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Sensory and Functional Properties of Wheat Stored Under Home Conditions

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SENSORY AND FUNCTIONAL PROPERTIES OF WHEAT STORED UNDER HOME CONDITIONS

by

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Marilyn M. Shumway

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Sensory and Functional Properties of Wheat

Stored Under Home Conditions

by

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Samples of wheat that had been stored in homes up to 48 years were collected with information about age and storage conditions. Germination, weight per bushel, protein, moisture, grade, and aroma were investigated. Volumes of gluten balls and bread made from ground whole wheat samples were measured. Sensory attributes of bread were evaluated by Quantitative Descriptive Analysis (QDA) for eight flavor and seven texture characteristics. Because of the tremendous variation in samples, generalizations on cause and effect are difficult to make. No one criterion was a perfect indicator of quality. A high percentage of germination was one of the better predictors of quality. Grade and weight per bushel were also related to quality. Rancid aroma in wheat forecasted off-flavors in bread. In general, older wheat did not make as good a quality of bread but there were outstanding exceptions. (122 pages)

INTRODUCTION

People have been storing grain for future use since prehistoric times (Tan et al., 1976). As part of a plan for self-reliance, many people in Utah store food. The goal is a one year supply. To minimize costs, basic foods that would maintain life, such as water, wheat and other grains, salt, honey or sugar, powdered milk, and cooking oil, are stored (Pike, 1992). A study of over 200 randomly selected families in Utah determined that wheat and flour storage is about 163 pounds per capita (Hendricks and Brennand, 1983). In spite of encouragement to use regularly and replace storage items to avoid waste, some of the wheat that has been stored has not been rotated. The wheat stored in many homes has not necessarily been stored under optimum conditions. This study was to evaluate the quality of the wheat stored under home conditions for extended periods of time and to ascertain what impact the storage conditions had on its bread-making quality.

REVIEW OF LITERATURE

Knowledge of cereals and cereal products requires some understanding of chemistry, biochemistry, physics, and engineering; consequently, volumes of information on subjects indirectly related to the quality of products made with stored wheat are available (Hoseney, 1986). Publications pertaining to wheat stored for planting and to grain stored for animal feed are also available (Bugbee, 1989a; Bugbee 1989b; Christensen, 1982). Studies directly related to long-term storage of wheat and flour for food are limited. Most studies directly related to products made from stored wheat, whole wheat flour, and white flour were made thirty or more years ago (Thiessen, 1933; Cuendet et al., 1954; Greer et al., 1954; Fifield and Robertson, 1959).

Important aspects of storage are preservation of quality and prevention of loss. We have learned that grain can be stored for several years without detectable losses of quality and quantity provided grain is stored under proper conditions (Tan et al., 1976).

Studies of Wheat and Flour Storage

Thiessen (1933) found that the quality of flour was maintained better in tightly closed cans than in cloth bags exposed to room atmosphere. Bread made from flour stored in bags up to 19 months received high scores. After 24 months in cans or 19 months in bags, the sensory quality of bread from the flour decreased (Thiessen, 1933).

Larmour et al. (1961) studied the effect of several types of packaging on the keeping quality of stored wheat flour and farina. Variables included twelve packaging materials and packaging sizes (from small packages for single family use to large bags or drums for bakeries), two moisture levels (as received from the mill and dried to 8 to 10%), outdoors and indoors, and two particle sizes (flour and farina). Storability was influenced notably by packaging material. Moisture content was stabilized by having a moisture barrier in the container. A small but consistent increase in loaf volume was observed in dried samples with a moisture content around 9%. Flours and farinas of 15% moisture showed a linear decrease in loaf volume. Changes in farina were slower than changes in flour. Throughout the 5 years of storage, bread from dried flour was acceptable even though some samples developed a foreign odor and flavor. Bread from higher moisture flour or farina had offensive off-odors.

Greer et al. (1954) examined white flour which had been stored in a British lighthouse at 10-20°C in gas tight cans for periods up to 27 years. There was no substantial damage to bread-making quality or sensory properties.

Fifield and Robertson (1959) reported that acceptable bread was made from flour milled from Marquis and Kanred wheat stored up to 33 years in a dry unheated room at Fort

Collins, Colorado. Most Marquis and Kanred wheat stored 33 years and Kanred stored for 30 years failed to germinate, but about 12% of some samples stored for 25 to 30 years germinated. Although storage did not have a consistent effect on protein content of grains, about one third of the samples showed a slight apparent loss of protein during storage.

Loaf volume is a measure of bread quality (Jones and Gersdorff, 1941). Cuendet et al. (1954) found marked decreases in volume of loaves made from whole wheat flour and untreated patent flour at 10% and 14% moisture stored for different periods of time. Loaf volume of bread made from whole wheat flour decreased after 26 weeks at 10% moisture and after 10 weeks at 14% moisture.

Post Harvest Improvement

Flour improves in bread-baking quality for a short time after grinding, then quality deteriorates slowly. During storage the potential bread-baking quality of freshly harvested wheat appears to improve moderately in a manner similar to that of flour but at a slower rate (Saunders, 1910). Apparently, the bread-baking quality of wheat will eventually deteriorate if the wheat is stored for a long period. However, under ideal storage conditions, this decrease in quality appears to proceed very slowly. Wheat germinates and makes acceptable bread after many years (Christensen, 1982).

Storage of Grain

Bugbee (1989a) maintained that choice of good seed for storage is important. Soundness, condition, and previous history influence respiratory activity and degeneration of grain. Grain with a high percentage of damaged kernels or other signs of unsoundness is more likely to deteriorate in storage than sound grain of the same moisture content (Christensen, 1974).

Moisture and Temperature

The key to a long storage life is the storage environment (Bugbee, 1989a). Environmental factors are interrelated and, consequently, difficult to discuss separately. Moisture and storage temperature are the principal environmental elements affecting seed preservation with moisture usually more critical than temperature (Bass, 1980). Generally, seeds remain viable longer and are fairly resistant to external conditions if they are dry (Christensen, 1974). The best storage environment is cold and dry.

Grain in a bin looks elusively uniform (Christensen, 1974). Grain stored at apparently safe moisture levels can be damaged by excess moisture. Relative humidity of air and storage temperature affect the moisture level in seeds since grain strives for equilibrium with interseed air. To preserve equilibrium, warm air traveling to a cooler region must give up moisture to grain, which results in increased moisture at that point. The important moisture level to know is the highest level, not the average. Stored grain includes living seeds, seed fragments, plant parts, weed seeds, fungi, and sometimes, mites and insects (Christensen and Meroduck, 1986). Living seeds respire. Respiration usually increases as temperature increases until enzymes are thermally inactivated, or substrate is exhausted, or oxygen is limited. Microorganisms will grow at locations where moisture is high and the microorganisms then generate more heat and moisture. Maximum moisture level for safe storage of wheat is generally 14% (Hoseney, 1986).

Thiessen (1933) said that in the home, safe moisture levels in wheat can be maintained by appropriate containers. Moisture gets into containers two ways: through the container walls by diffusion and through leaks in the seal. Water vapor slowly leaks through plastic but diffusion through heavy plastic is very slow. Heavy polyethylene containers with tight fitting lids are suitable as are glass and metal containers. Metal containers can be placed on a shelf or on slats to avoid moisture accumulation on the bottom. Containers should have nearly air-tight lids (Whitesides, 1989). Gallon cans with plastic lids make good containers if the lid is made moisture resistant with two layers of electrical tape (Bugbee, 1989b). Plastic bags can be used to store dry wheat. Only materials labeled for food should be used because some plastic materials can impart off-flavor or toxicants to wheat (Whitesides, 1989).

Damage from Rodents, Insects, and Fungi

Excessive moisture in wheat during storage can aggravate damage from insects, molds, heat, sprouting, and rodents. These factors can injure the wheat or lower germination, as well as causing unwanted changes in odor, sanitary quality, nutritive value, or chemical components. Wheat and its products stored improperly are vulnerable to attack from insects and rodents. These small furtive pests often cause large losses before they are discovered (Matz, 1959). Rodents ravage wheat, contaminate it with their filth, and carry diseases. A rat can consume 40 pounds of grain in a year as well as rendering ten times that amount unfit for human consumption with urine, droppings, and fur. Mice, which are smaller, more numerous, and more universally distributed than rats, do similar damage (Matz, 1959).

Insects jeopardize the quality of grain several ways. Some eat only the broken kernels while others devour whole kernels. All contaminate the grain. Even if the fragments of insects that get in wheat may be harmless, they are objectionable (Christensen, 1982). Insects reduce flour yields and increase temperatures (Pomeranz, 1971). Low temperature and low moisture will keep insects as well as fungi from growing and becoming a problem.

Where there are insects, there may very well be fungi. The granary weevil, *Sitophilus granarius*, has a symbiotic relationship with the fungus *Aspergillus restructus*. In a study by Christensen and Meroduck (1986) granary weevil were first treated to kill external contaminants and then put on agar to detect fungi. After ten days *A. restrictus* grew from cultures from the snout and anal opening of nearly all the weevil.

Mold-caused problems are inconspicuous at first. Damage begins with reduction in vigor and percentage of germination, and discoloration of wheat germ, followed by discoloration of the entire kernel, accompanied by mustiness, caking, and sometimes heating to ignition (Christensen and Meroduck, 1986). The degree of infestation is determined by both the moisture and the temperature of the seeds. Although metabolism of seeds is very low, it still can cause a rise in temperature of the seeds in bulk. Bacterial and fungal infestation also adds to the temperature rise. Temperature increases, in large storage areas, in extreme cases can cause charring and even fires. Less severe heating may change the proteins so they become unsuitable for bread baking (Duffus and Slaughter, 1980). Biochemical changes, production of toxins, and loss of weight are other forms of spoilage caused by fungi and bacteria (Christensen and Kauffman, 1969).

One of the poorly defined types of damage in wheat associated with storage deterioration is the condition known in the grain trade as germ-damaged or "sick" wheat. It is manifested by kernels with a dull appearance, in which the germs are dead and show differing degrees of darkening (Milner and Gedds, 1954). Mold growth is usually present in commercial samples of such grain. One view is that the discoloration associated with germ-damaged wheat is due to a browning reaction of the Maillard type. "Sick" wheat is recognized by the turning of the germ from normal light yellow to light tan, brown, and finally, dark mahogany. This damage reduces the commercial grade. McDonald and Milner (1954) extracted wheat germ with ether at three different temperatures and varying moistures and promoted the onset of browning in fresh unprocessed wheat germ by elevated temperature and moisture. The browning invariably preceded mold growth. Wheat-germs that have died turn light brown, then darken and decay. Instead of being flattened and retrieved as nearly pure germs during milling, they crumble and end up as dark spots in the flour. Such germs are high in fatty acids because storage fungi convert the oils in the germs into fatty acids as they decay the germs. The flour and products made from it taste rancid. Wheat with more than a small percentage of damaged kernels is unsuitable for milling into flour (Hoseney, 1986).

Quality Assessment

Wheat that is bright, sound, fully mature, clean, and free of foreign material or any evidence of damage is best for storage (Zeleny, 1954). Stored wheat should be of high quality and that quality preserved during storage (Tan et al., 1976). Variations in wheat quality do occur since soil, climate, and innate characteristics as well as handling and storage determine wheat quality (Christensen, 1974; Pomeranz, 1971). Naturally, wheat that is damaged because of improper handling or storage or that includes foreign material is of inferior quality and results in economic loss (Christensen, 1974).

Grade

One estimation of grain quality is grade. Large quantities of wheat as harvested, stored, transported, or traded usually have a grade which provides an estimate of properties of the grain (Shellenberger, 1980). When wheat is graded in the U.S., it is classified as Hard Red Spring, Durum, Red Durum, Hard Red Winter, Soft Red Winter, White, or Mixed Wheat. The wheat classes (except Red Durum) are divided into subclasses on the basis of kernel texture, geographical origin, or other attributes. Within each subclass, assuming that a number expresses end-use properties and economic value, wheat is assigned numerical grades from one to five and a sample grade on the basis of factors such as protein content, kernel hardness, test weight per bushel, heat damage, proportion of shrunken or broken kernels, presence of foreign matter, damaged kernels, insect infestation, presence of other wheat varieties, and freedom from objectionable odors (Table 1). Because moisture

Table 1--Official grain standards
Class IV. Hard red winter wheat

Grade No.	Min. Wt/Bu	Damaged Kernels Total	Damaged Kernels Heat Damage	Foreign Material Total	Foreign Material Not Grains	Foreign Material Other Wheat
	lb	%	%	%	%	%
1	60	2	0.1	1	0.5	5
2	58	4	.2	2	1.0	10
3	56	7	.5	3	2.0	10
4	54	10	1.0	5	3.0	10
5	51	15	3.0	7	5.0	10

content is so important to storage stability and yield, all numerical grades have a moisture limit. Those exceeding moisture limits are labeled "tough" (Plyer, 1973; Shellenberger, 1980). The term "tough" comes from the moisture added to toughen the bran so it breaks off in large pieces that are easily removed when grain is milled. Two kinds of debris (dockage and foreign material) are considered. Dockage (chaff, stalks, grain dust, other seeds, etc.) is reported to the nearest 0.1%. Foreign material (nonwheat material remaining when dockage is removed) reduces grade (Matz, 1991).

Test Weight per Bushel

A major factor affecting grade is test weight. A known volume of wheat is weighed, and from that the weight of a Winchester bushel is established (Matz, 1991). The legal standard test weight of wheat in the United States is 60 pounds per bushel, but wheat can weigh as much as 64 pounds or as little as 45 pounds per bushel (Pomeranz, 1971).

At lower test weights, a relationship exists between flour yield and test weight. Flour yield from immature or badly shriveled kernels is less than flour yield from plump kernels. Correlation between test weight and flour yield goes down as test weight increases (Shellenberger, 1980).

Wheat Protein

Both genetic and environmental factors affect protein quantity and quality. Protein differences due to environment are larger than those ascribable to genetic effects. Key environmental factors that influence protein content are soil, nitrogen availability, and amount and distribution of precipitation (Johnson and Mattern, 1987).

Proteins of wheat flour are customarily associated with baking performance (Pence, 1962). Unique characteristics allow wheat proteins to form gluten, a cohesive, extensive mass, when mixed with water (Plyer, 1973). Gluten is composed of glutenin and gliadin. The dough will retain gas developed during fermentation and yield a light bread when baked. Because of the importance of wheat proteins in baking, a review of protein is in order. Classification of proteins based on solubility adopted by the American Physiological Society in 1908 is still used (Plyer, 1988). Proteins are classified as albumins, globulins, prolamins, and glutelins. Albumins are soluble in water. Globulins require the addition of neutral salts to the solvent.

Prolamins including wheat's gliadin are soluble in aqueous alcohol. Glutelins such as wheat's glutenin are soluble in mild acid or base (Pence, 1962).

Glutenin consists of relatively large molecules in the range of 50,000 to over 1,000,000 molecular weight, whereas gliadin molecules are smaller and more uniform with average molecular weights of 20,000 to 40,000. The higher molecular weight of glutenin seems to be from linking smaller molecular-weight units with disulfide bonds. When disulfide bonds are broken, glutenin loses its tough, elastic-cohesive character, and its molecular weight approaches that of gliadin. With starch gel electrophoretic patterns, Kozmin (1935) showed decreases in glutenin and increases in gliadin-like components as wheat flour aged.

Approximately 40% of the amino acids in gluten proteins are glutamic acid. Another 10 to 13% of the amino acids in gluten proteins are proline. This results in steric hinderance so normal helical structures of coiled protein chains are not formed (Pence, 1962).

Methods of protein analysis available include 1) the conventional and modified Kjeldahl; 2) dye binding; 3) alkaline distillation; 4) elementary nitrogen; 5) neutron activation and related methods; 6) Near Infrared Reflectance (NIR). Several methods give good results. Until recently the well-established Kjeldahl method has been used almost exclusively to determine nitrogen content of grain

(Shellenberger, 1980). The Kjeldahl test is based on the titration of ammonia released when excess alkali is added to an acid digest of flour. This measures total organic nitrogen, which is converted by factors to estimate protein. Some disadvantages of the Kjeldahl test are the necessity of handling corrosive reagents, the caustic fumes evolving from the digests, and the time required. Other techniques are standardized against the Kjeldahl. Each procedure has advantages and disadvantages. These methods of protein testing on grain vary in cost, space, skill of operation, capacity, and speed (Shellenberger, 1980). The Near Infrared Reflectance method for estimating protein content of cereal has become a routine procedure that can be highly automated, as it has in Canada for marketing grain on a guaranteed protein basis (Williams and Norris, 1987). The protein test, a good test to judge wheat protein quantity, is, nonetheless, far from the absolute answer, because no single test can estimate the quality of a complex biochemical system like a wheat kernel (Matz, 1991).

The term "strength" is used to indicate the quality of flour made from wheat for making pan bread. Strength is a function of protein quality and quantity. Usually the more protein a flour has, the stronger it is. The assumption is that a certain amount of the protein is gluten, the structure-forming part of flour (Matz, 1972). Quantity of protein is easily determined by one of the above standardized procedures, which can be duplicated in other labs. Quality of protein, however, is not as easily defined because it is affected by characteristics of the wheat kernel and related to end use (Plyer, 1988). The protein test measures quantity of protein but is not conclusive in identifying wheat that will produce most desirable bread. The strength of bread flour is measured by its ability to develop a strong dough as water and other components are mixed with flour. Best bread flours absorb water well. One simple test of strength is the sedimentation test. The sedimentation test is based on the fact that gluten protein absorbs water and swells when treated with lactic acid, and the amount of water absorbed or the amount of swelling depends on the quality of the gluten (Quisenberry and Reitz, 1967). The sedimentation test is used to appraise wheat quality. Advantages of this test are the speed and simplicity and the small sample size required (Quisenberry and Reitz, 1967). Typical sedimentation values range from 10 to 70. Wheats with values over 60 usually have superior gluten quality, superior baking strength, and can be mixed with weaker flour. Wheat with sedimentation values between 40 and 59 normally has a good protein content and the quality of the gluten is normally good. Wheats with a value of 40 or more are favored for commercial bread-making. Grain with values between 20 and 39 are usually utilized for "all purpose" flour. Wheat with values under 20 is generally soft wheat, which is used for cake, pastry, and cookies (Pinckney et al., 1957).

Another measure of strength is the ability of dough to hold carbon dioxide liberated by yeast during fermentation. Quality evaluations of a wheat sample should be made within the framework of intended use. For bread it is generally believed that baking properties can be expressed in terms of loaf volume (Jones and Gersdorff, 1941).

The gluten washing test is a physical assessment applied to hard wheat flour in the U.S. that provides valuable quality information. The test involves washing starch from flour-water dough and collecting the cohesive gluten mass. Because the test is time consuming and hard to reproduce, it is presently being replaced largely by protein tests (Matz, 1959).

Wheat Defects

Certain wheat kernels are classified as "yellow berry" because they have a yellow-colored bran coat and a starchy, mealy endosperm instead of hard, vitreous, flinty kernels when comparing the same cultivar grown in the same soil under the same conditions. Kernels appear yellow because of reflectance caused by air spaces in the endosperm. The protein content of yellow berry kernels is less than dark, hard, vitreous kernels of wheat in the same sample. Yellow berry wheat is given a grade price discount because of lower protein content (Williams and Norris, 1987).

Another defect in wheat is sprout damage. Wheat with sprout damage can be milled to improve or lessen the quality of the flour. Hard wheat flour is usually improved by more diastatic activity by addition of cereal fungal enzymes, so a limited amount of germinated, high-diastatic wheat can be beneficial. However, too much germinated wheat causes undesirable results because of excess α-amylase activity (Shellenberger, 1980). Diastatic activity is defined as activity related to changing starch to sugar (Flexner, 1988). Diastatic activity is more critical in products, like bread, which require fermentation (Shellenberger, 1980).

OBJECTIVES

The primary objective of this study was to analyze the relationship(s) between the current quality of wheat samples which have been stored under various conditions with their functional and sensory properties. The following questions were addressed:

1. What was the impact of long-term storage under home conditions (temperature, moisture, containers) on the quality of wheat and bread made from it?
2. What were differences in characteristics between wheat that had been stored for extended periods of time and those of control wheat?
3. What recommendations can be made for purchase and storage of wheat?

MATERIALS AND METHODS

Long-term stored wheat was acquired mostly from county extension agent's contacts. Information was collected on length of storage and storage conditions (temperature, year stored, type of container, and storage area). Walton Wheat, which is quadruple cleaned, between 14 and 16% protein, and 10% or less moisture, was chosen as the control.

Investigations included bread-baking tests with sensory evaluation using Quantitative Descriptive Analysis (Stone et al., 1974) and loaf volume measurement, gluten washing and gluten ball weight and volume measurements, germinating wheat samples, measuring weight per bushel, proximate analysis for protein and moisture, sedimentation tests, grading, evaluating aroma, and statistical analysis.

Bread Samples

Wheat for bread was ground twice through a Grind All (model R-10-D) grinder. Bread samples were made using the following formula, which was developed by combining Miller's (1981) formula with Mondy's (1980) using a straight dough method.

Whole Wheat Bread

848.	g	Whole wheat flour
7.	g	Rapid rise yeast
50.	g	Instant nonfat dry milk
40.	g	Oil
37.5	g	Granulated sugar
8.	g	Salt
660.	ml	43.3°C (110°F) tap water

Rapid rise yeast, nonfat dry milk, and part of the flour were combined. Salt, sugar, and oil were added with water, and the dough was mixed for 5 minutes at speed 4 while adding flour, then for 5 more minutes at speed 10 in a K-4B model Kitchen Aid Mixer. Dough was allowed to rise about an hour until it passed the "ripe" test, then punched down and allowed to rise another 30 minutes. After being divided into loaves, the dough was allowed to rest 10 minutes, formed into 775 g loaves, and allowed to rise 25 minutes. Loaves were baked at 218°C (425°F) for 10 minutes, then for 25 minutes at 191°C (375°F), cooled on a rack, bagged, labeled, and held in a freezer until sensory testing. A slice from each sample loaf was photocopied before sensory evaluation was conducted (Appendix B).

Sensory Evaluation

Thawed loaves were sliced mechanically for uniformity for sensory evaluation. Quantitative Descriptive Analysis was used to characterize perceived sensory attributes of the bread in quantitative terms using interval scaling (Stone et al., 1974). From a pool of 31 potential panelists, 15 (10 males and 5 females) were selected. Sensory panelists were selected for their ability to detect the rancid flavor in bread made with 10% whole wheat flour from 1973 and flour from control wheat compared to bread made with flour from control wheat alone and for the panelist's ability to replicate judgments. Through panel discussion specific texture and flavor characteristics as shown on the sample ballot were identified and used as the intensity scales (Fig. 1). Data were compiled by measuring in cm from the first tick mark on each line to the point marked by the panelist.

Loaf Volume

The volumes of the loaves of bread were measured by rape seed displacement. A rectangular container slightly larger than the loaves of bread was filled with rape seeds, avoiding packing, then leveled. The loaf of bread was placed in the container, and the container was again filled with rape seeds. The difference in the volume of the seeds in the container with and without the bread is the volume of the loaf.

Gluten

Gluten balls were made from 200 g freshly ground wheat and 155 ml water, which were combined and mixed as in the bread-making procedure. The dough was then washed until liquid came out clear, indicating all starch had been washed out. The resulting spongy gluten was baked at 232.2°C (450°F) for 15 minutes followed by 149.9°C (300°F) for 35 minutes. Gluten balls were weighed after baking. Final volume of balls was measured by rape seed displacement.

Name________________________

Texture Characteristics

Grain

Fine — Coarse

Porosity

Compact — Light

Crumbly

Not — Pronounced

Gummy (cohesive)

Not — Pronounced

Adhesive (sticks to teeth)

Not — Pronounced

Chewy

None — Pronounced

Moisture

Dry — Wet

Fig. 1--Quantitative Descriptive Analysis (QDA) ballots used to evaluate texture and flavor of bread

Flavor Characteristics

Rancid (linseed oil)

None — Pronounced

Stale

Fresh — Off-flavored

Nutty/Wheaty

None — Pronounced

Yeasty

None — Pronounced

Salty

None — Pronounced

Sweet

None — Pronounced

Bitter

None — Pronounced

Astringent (mouth pucker)

None — Pronounced

Fig. 1--Quantitative Descriptive Analysis (QDA) ballots used to evaluate texture and flavor of bread (continued)

Germination

Loss of viability is one yardstick used for measuring grain damage as germination can be determined fairly simply and is readily impaired by unsatisfactory storage conditions (Christensen, 1982).

For germinating, 50 sound kernels of each sample were placed in glass petri dishes on filter paper dampened with water and covered. To avoid mold contamination, petri dishes were washed in the dishwasher. In preliminary tests 1/3 teaspoon lime in a gallon of warm water was used to soak kernels as a mold inhibitor. Mold still grew. In final tests the kernels were surface sterilized with 10% chlorine bleach. Care was taken that the kernels not touch each other. Germinating wheat kernels were observed daily and dampened with double distilled water from a spray bottle. Percent germination was determined on the sixth day.

Weight per Bushel

Bushel weight was determined using a Seedburo test weight machine. The wheat sample was poured through a funnel into the one-pint container for weighing to assure uniform packing. The grain in the measure was leveled with a zig-zag motion with a round striker. The results were reported in pounds per Imperial bushel (Pomeranz & Shellenberger, 1971).

Protein

Protein content of the wheat samples was analyzed in triplicate using the Kjeldahl method according to directions in AOAC (1980). A Kjeltec Auto 1030 digestion system was used. Initially a Semi-Micro Kjeltec Automatic Distiller and Titrater was employed. Later the Labcono Rapid Kjeldahl System Rapid Still II and hand titration were used. Kjeldahl results were compared with data obtained using Near Infrared Reflectance, AACC approved method 39-10 (Williams and Norris, 1987).

Sedimentation Tests

A modified sedimentation test described by Pinckney et al. (1957) was used. Wheat was coarsely ground and sifted to remove most of the bran. In a 100 ml graduated cylinder with 180 to 185 mm between the zero mark and the 100 ml mark, 3.2 grams of the crude flour were mixed with 50 ml of distilled water containing brom phenol blue for 5 minutes. Twenty-five ml isopropyl alcohol-lactic acid reagent was added, and the mixture was agitated for 5 more minutes, then allowed to stand in an upright position. The volume of the swollen sediment after a 5-minute standing period was the sedimentation value.

Moisture

Moisture content was measured by Near Infrared Reflectance (NIR) and by oven drying. In the oven method, 2 g of flour were dried for 1 hr at 130±3°C. Dry flour was cooled in a desiccator and weighed soon after it returned to room temperature (AOAC, 1984).

Grade

Numerical grades from 1 to 5 were assigned based on percent damaged kernels, foreign material, and other defects. Grading details are shown on Table 1 in the literature review section.

Aroma

Wheat aroma was judged by smelling wheat samples under ambient conditions. Scores from 1 to 6 were assigned, with higher scores being given to the more objectionable odors using the method described by Cuendet et al. (1954). Averages of scores given by three individuals were used for aroma value.

Statistics

Data from chemical and physical measurements, storage conditions, and sensory information were compiled. Data from the 24 different samples of stored wheat used in the study were analyzed individually, then pooled into general categories to facilitate data handling and to allow for more replication. Table 2 shows groupings selected and number in each group. Sensory and physical data were analyzed by one-way analysis of variance, using the general linear model

(GLM) approach. Differences between means were evaluated using Least Significant Differences. The computer programs used in these analyses were Statistical Analysis System ® (SAS, 1989) and Minitab ® (Minitab, 1988). Cricket 1.3 was used for generating figures.

Table 2--Grouping for statistical analysis

Assigned Number	Age in Years	Number in Group
1	1-2	3
2	7	1
3	13-14	4
4	15-17	5
5	18	2
6	20-27	4
7	30-33	4
8	48	1

Assigned Number	Storage Temperature and Conditions	Number in Group
1	Uniform Warm Temperature Main Floor	3
2	Uniform Cool Temperature Basement	15
3	Fluctuating Temperature Out Building	5

Storage temperature and conditions for one sample were not available.

Assigned Number	Pounds per Bushel	Number in Group
1	<60	3
2	60-61.9	5
3	62-63.9	9
4	64+	7

Assigned Number	Percent Protein	Number in Group
1	<12.99	11
2	13.0-13.99	6
3	14.0-14.99	5
4	15.0+	2

Assigned Number	Gluten Ball Volume (ml)	Number in Group
1	<299	12
2	300-399	6
3	400-499	3
4	500+	3

Assigned Number	Loaf Volume (ml)	Number in Group
1	<1400	2
2	1400-1499	8
3	1500-1599	5
4	1600-1699	5
5	2000+	4

Assigned Number	Sedimentation	Number in Group
1	20-30	15
2	33-38	6
3	40-49	2
4	50+	1

Assigned Number	Percent Germination	Number in Group
1	0-25	11
2	26-50	5
3	51-75	1
4	76-100	7

RESULTS AND DISCUSSION

Samples, Age, and Storage Conditions

Twenty-four samples of wheat stored under home conditions were collected from Utah, Idaho, and Wyoming, mostly through Utah Cooperative Extension Agents. Wheat's genetic differences were illustrated in the variation in the wheat samples collected. Wheat comes in many shades of red and white. Texture can be hard, soft, starchy, vitreous, or yellow berry (Quisenberry and Reitz, 1967). Most samples were hard red wheat. At least one sample was about half soft white spring wheat. Several samples had some yellow berry. The wheat samples varied greatly in every characteristic measured.

Some samples were stored on the main floor, some in the basement, and some in unheated outbuildings. Samples had been stored in fairly moisture proof containers except three that were stored in cardboard drums (Table 3). Moisture levels of collected samples ranged from 7.70% to 9.56% with an average of 8.73%, all well under the recommended safe level of 14% moisture (Table 4). Over long periods under various storage conditions, there may have been fluctuations in the moisture content, particularly of samples stored in cardboard containers.

Percent of kernels that germinated ranged from zero to nearly 100% in the various samples. Individual analysis of

Table 3--Summary of storage conditions and general description of wheat samples

#	Age Years	Container	Temperature	Insect	Treatment	Describe Character
1	1	Double Plastic Bag	Uniform Warm	No	4 X Clean	
2	2	Double Plastic Bag	Uniform Warm	No	4 X Clean	
3	2	White Plastic Bucket	Uniform Cool & Fluctuating	No		Pale
4	7	Metal Can	Fluctuating	No		Dull
5	13	Plastic-Lined Metal	Uniform Cool	No		Plump Undamaged
6	13	Green Plastic Bucket	Cool Warm Fluctuating	No		Lt. Color
7	14	Plastic-Lined Metal	Uniform Cool	No	Bay Leaf	Few Hulls
8	15	Metal	Uniform Cool	No		Few Other Seeds
9	17	Metal Can	Uniform Cool	No	Dry Ice	Vitreous
10	17	Metal Can	Uniform Cool	No		Dull Broken

(table continued)

#	Age Years	Container	Temperature	Insect	Treatment	Character
11	17	Cardboard	Fluctuating	No	No Spacer Between Concrete & Container	Vitreous
12	18	Plastic Bucket	Uniform Cool	No		Vitreous Few Hulls
13	18	Moisture Proof	Uniform Cool & Fluctuating	Some		
14	20	Metal Drum	Uniform Cool	No		
15	22	Plastic-Lined Metal	Uniform Cool	No	Dry Ice	Hulls Broken
16	25	Metal Drum	Uniform Warm	No	Dry Ice	Few Hulls Odd Seeds
17	25	Metal Barrel	Uniform Warm	Many	Not Tasted	Lt. Color Dusty
18	26	Plastic-Lined Metal	Fluctuating	No		Whole Kernels
19	27	Metal Barrel	Cool & Fluctuating	No		Lt. Color
20	30	Metal Drum	Fluctuating	Some		Spring 1/2 Soft

(table continued)

#	Age Years	Container	Temperature	Insect	Treatment	Character
21	30	Cardboard Drum	*	No	CCl_4 Not Tasted	Some Broken
22	32	Plastic-Lined Metal	Fluctuating	No	Dry Ice	Light Color
23	33	Cardboard	Fluctuating	No		Few Broken
24	48	Plastic-Lined Metal	Uniform Cool			Vitreous

*Storage temperature and conditions not available

Table 4--Results of tests on wheat samples

#	Aroma	Grade	Wt/Bu Pound	Percent Moisture	Percent Protein NIR	Percent Protein Kjeldahl	Percent Germination
1	2.00	1	62.5	8.36	17.00	17.05	98.70
2	2.33	1	66.8	7.96	13.32	13.30	98.70
3	2.33	2	66.5	8.61	14.55	13.37	76.00
4	2.00	2	58.4	8.67	13.73	13.47	63.00
5	2.00	3	66.3	9.09	14.85	13.90	88.70
6	2.33	2	63.9	8.74	10.19	10.45	78.00
7	3.00	1	64.0	8.40	12.93	12.60	31.00
8	2.33	1	64.4	9.00	13.87	13.90	95.30
9	2.33	1	64.6	8.67	12.20	13.27	24.70
10	5.33	4	63.1	8.75	13.94	11.85	14.00
11	3.67	3	62.6	9.57	17.78	17.07	0.00
12	2.67	2	61.3	7.70	11.74	11.70	0.00
13	3.33	2	60.9	9.56	13.87	12.60	38.00
14	3.00	1	65.0	8.67	8.73	9.29	40.00
15	3.33	3	61.7	8.25	12.81	12.40	10.00
16	3.33	2	61.4	8.15	13.87	13.80	35.00
17	3.33	5	62.0	8.78	10.34	9.98	1.00
18	2.33	2	63.0	9.10	12.93	12.70	84.00
19	2.00	4	59.4	9.06	14.78	14.00	2.00
20	2.33	4	65.2	8.78	13.42	12.30	44.00
21	3.00	4	63.2	7.60	12.11	11.30	0.00
22	2.67	3	57.8	9.15	14.67	14.95	0.00
23	3.67	5	62.1	7.76	13.56	13.37	18.00
24	2.67	1	61.1	8.78	14.58	13.57	4.00

kernel germination showed that the percent of kernels that germinated decreased as age increased (Fig. 2) with some exceptions. A 15-year-old sample with 95.3% germination and a 26-year-old sample with 84% germination remained more viable than other samples of similar ages. No consistent pattern in storage method or appearance of grain explained the comparatively high quality of these particular samples.

Grades varied from 1 to 5. Seven samples including the newest and the oldest samples were grade 1. Other samples were lower grades. Weight per bushel ranged from 58 to over 64 pounds per bushel.

Percent protein, sedimentation, and gluten ball volume exhibited similar characteristics from different angles. Protein ranged from less than 9% to over 17% (Table 4). Sedimentation values varied from 19 to 65 (Table 5). Sedimentation values of 60 or more usually indicate over 14% protein and superior gluten quality. Sedimentation values in the 40 to 59 range usually indicate 12-14% protein and good gluten quality (Quisenberry and Reitz, 1967). Only sample one, the new one-year-old control, had a sedimentation value above 60. Two samples, a 17-year-old sample and a 32-year-old sample, had values in the 40 to 59 sedimentation range. The other 21 wheat samples had sedimentation values of 20 to 39. Sedimentation values may have been low initially, or degradation may have taken

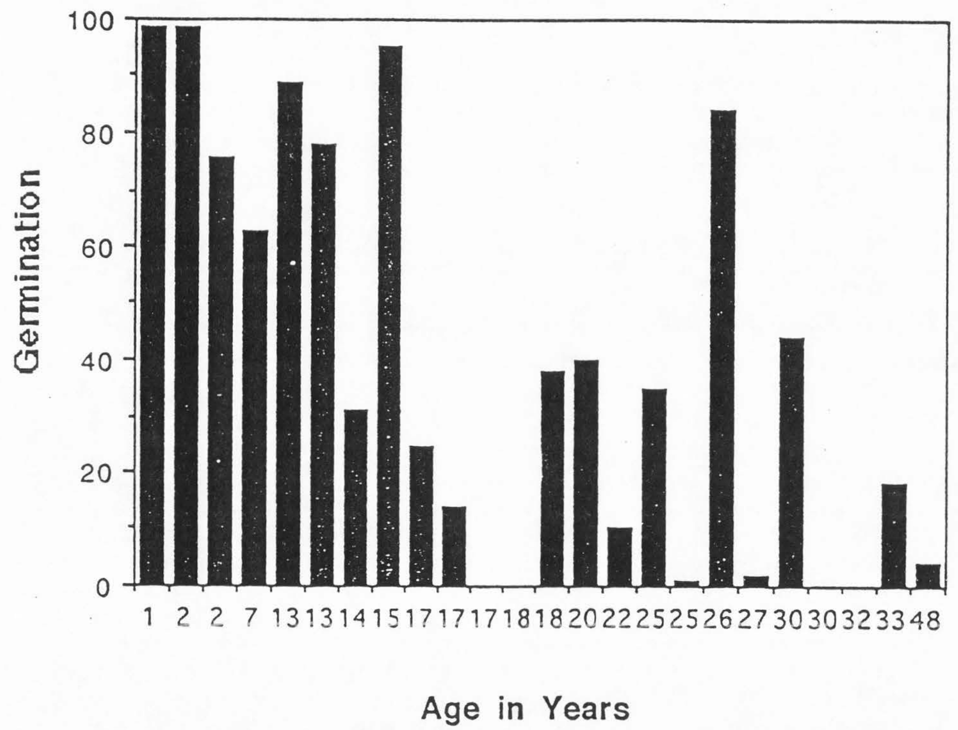

Fig. 2--Relationship of length of storage in years to percent of kernels that germinated

place. The sample with the largest gluten ball volume was 32 years old (Table 5). Samples with the smallest gluten

Table 5--Results of tests on wheat samples reflecting baking characteristics

		Gluten Ball		Loaf
Sample	Sediment	Baked Wt (g)	Vol (ml)	Vol (ml)
1	65	58.38	554	1480
2	38	51.60	386	1575
3	35	56.12	265	2015
4	23	69.44	299	1670
5	35	40.71	561	1845
6	23	31.12	180	1690
7	28	50.04	148	1425
8	24	48.95	148	1610
9	22	16.26	341	1340
10	30	50.00	448	1580
11	41	66.01	457	1545
12	34	43.32	295	1420
13	23	37.61	348	1730
14	20	27.69	165	1460
15	25	31.93	163	1560
16	29	43.03	420	1640
17	30	17.99	146	1725
18	27	58.22	290	1580
19	26	54.90	365	1475
20	33	49.12	277	1690
21	24	12.20	87	1370
22	43	41.63	763	1845
23	30	46.46	263	1460
24	35	40.29	145	1290

ball volumes were 14, 15, 25, 48, and 30 years old with 148, 148, 146, 145, and 87 ml volume, respectively.

Sample ages ranged from new to 48 years old based on the memory of those donating the sample. Samples were arranged from youngest to oldest and assigned numbers in that order. Distribution by year of storage is a problem in a study such as this. Between 13 and 33 years there were no gaps of more than 2 years. Correlations of physical, chemical, and sensory traits are tabulated in appendix Table A.1. Table 6 lists correlation coefficients greater than plus or minus .400 for physical and chemical properties.

Panelists found significant differences among the individual samples for all texture and flavor characteristics measured except yeasty and salty (Table 7).

Effect of Age on Wheat Quality

In contrast to individual data, analyses of sensory characteristics grouped by age showed no significant differences (Table 8). QDA flavor scores were only slightly related to increased storage time. Individually, both rancid and stale ratings increased slightly but not significantly as age of sample increased (Fig. 3a). The desirable flavors, nutty and sweet, decreased but not significantly as age increased (Fig. 3b). With grouped data, nutty and sweet QDA scores (R= -.485 and -.356,

Table 6--Correlations greater than ± .400 for physical and chemical properties

Measurements		Correlation
Age	Grade	.506
Age	Bushel Weight	-.427
Age	Germinate	-.594
Age	Nutty	-.485
Aroma	Grade	.407
Aroma	Germinate	-.571
Aroma	Rancid	.541
Aroma	Stale	.432
Grade	Nutty	-.516
Grade	Yeasty	.440
Grade	Sweet	-.438
Sediment	Protein	.738
Sediment	Gluten Ball	.661
Protein	Gluten Ball	.571
Protein	Sweet	-.532
Bushel Weight	Rancid	-.426
Bushel Weight	Stale	-.410
Bushel Weight	Nutty	.586
Gluten Ball	Sweet	-.403
Loaf Volume	Porosity	.515
Loaf Volume	Gummy	-.519
Loaf Volume	Adhesive	-.442
Loaf Volume	Rancid	-.481

Table 7--Analysis of variance on sensory characteristics based on sample

Dependent Variable	DF	MSE	F Value	P
Grain	23	55.66	8.71	.0001
Porosity	23	81.76	14.79	.0001
Crumbly	23	97.55	15.62	.0001
Gummy	23	39.93	7.42	.0001
Adhesive	23	19.45	3.30	.0001
Chewy	23	27.91	4.87	.0001
Moist	23	28.27	6.06	.0001
Rancid	23	22.72	2.38	.0003
Stale	23	28.46	3.13	.0001
Nutty	23	13.88	2.13	.0016
Yeasty	23	1.70	.41	.9938
Salty	23	2.21	.44	.9894
Sweet	23	13.40	3.40	.0001
Bitter	23	11.79	1.90	.0071
Astringent	23	13.68	1.66	.0268

respectively) decreased slightly as age increased. Relationships between age and rancid (R = .413) and between age and stale (R = .277) were small. When grouped by age, germination was the most significant physical or chemical characteristic based on grouped age in years (P = .006). Percent germination decreased as age increased. The mean germination rate decreased in a fairly linear manner with increase in age in years (Table A.6). In the grouped analysis of variance, age of wheat sample did not have a statistically significant effect on loaf volume, gluten ball

Table 8--Analysis of variance on sensory characteristics based on samples grouped by age

Dependent Variable	DF	Mean Square	MSE	F Value	P
Grain	7	1.832	2.056	.89	.54
Porosity	7	1.471	3.241	.45	.85
Crumbly	7	1.019	4.467	.23	.97
Gummy	7	.701	1.838	.38	.90
Adhesive	7	.475	.796	.60	.75
Chewy	7	.541	1.122	.49	.83
Moist	7	.571	1.219	.47	.84
Rancid	7	.922	.786	1.17	.38
Stale	7	1.263	.855	1.48	.25
Nutty	7	.421	.415	1.01	.46
Yeasty	7	.121	.246	.49	.82
Salty	7	.016	.097	.17	.99
Sweet	7	.592	.498	1.19	.37
Bitter	7	.446	.393	1.14	.40
Astringent	7	.484	.490	.99	.48

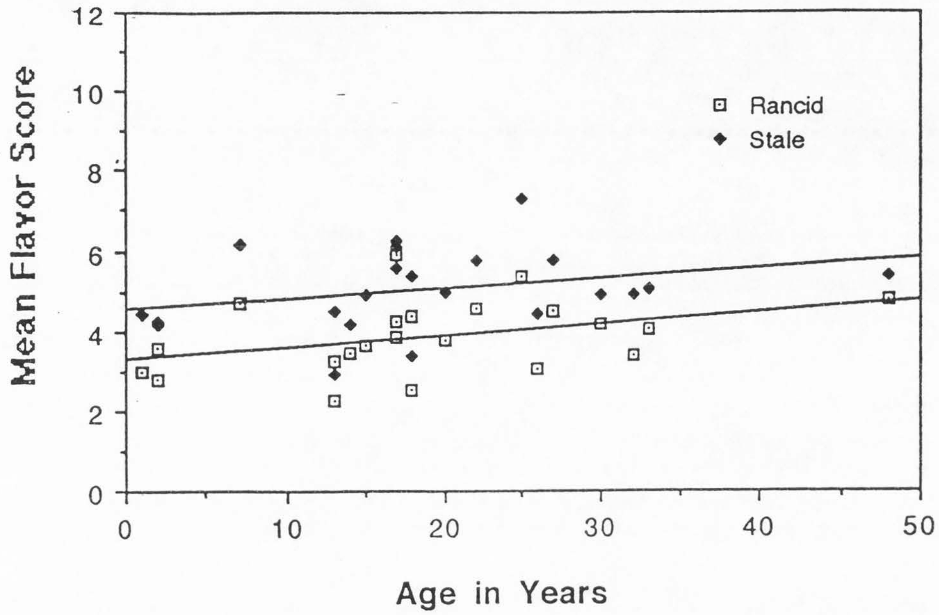

Fig. 3a--Comparison of mean rancid and stale scores to age

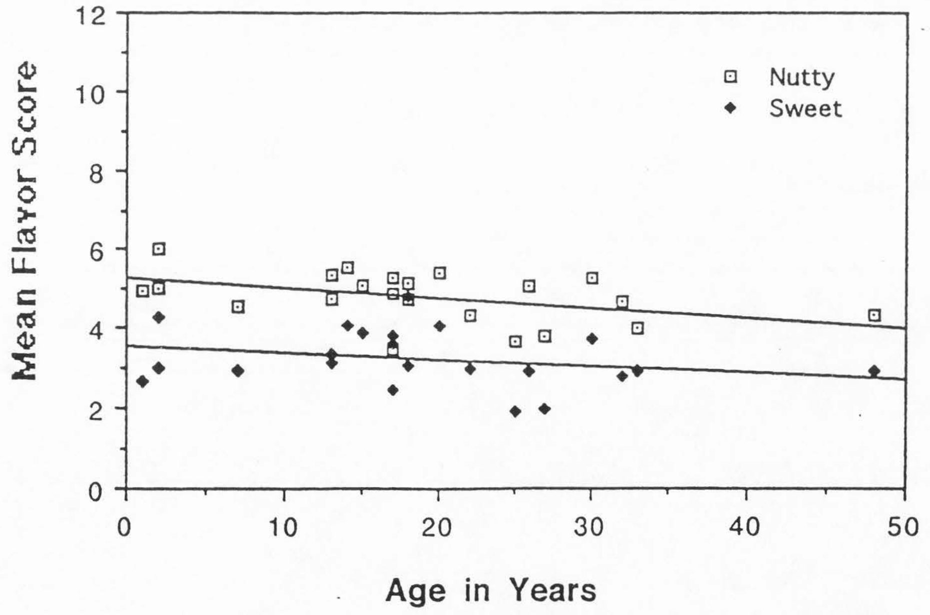

Fig. 3b--Comparison of mean nutty and sweet scores to age volume, bushel weight, sediment, porosity, or aroma (Table 9). One 2-year-old sample had the largest loaf volume (2015 ml). The 48-year-old sample, the oldest sample, had the smallest loaf volume (1290 ml). One 2-year-old sample had high volume while the other 2-year-old sample had low volume, resulting in an average lower than that of the 32-year-old sample (Table 5). The smaller loaf volume of the newest sample and one 2-year-old sample may illustrate the hypothesis of post harvest improvement in loaf volume (Christensen, 1974). Between the 2-year-old sample with the largest loaf volume and the oldest sample with the smallest loaf volume the decrease was not linear with increasing age (Fig. 4a). Other factors besides age must enter into the variation in loaf volume. Age groups six and seven, whose loaf volumes were above 1590 like younger samples, were more viable than others near their age.

Germination

The ability of wheat to germinate was considered as a possible indicator of quality of wheat. Grouping the samples by percent of kernels that germinated shows a linear relationship to loaf volume but differences are not significant (Fig. 4b). Loaf volumes of samples that germinated 0 to 25% averaged 1510 ml (Table A.10). An

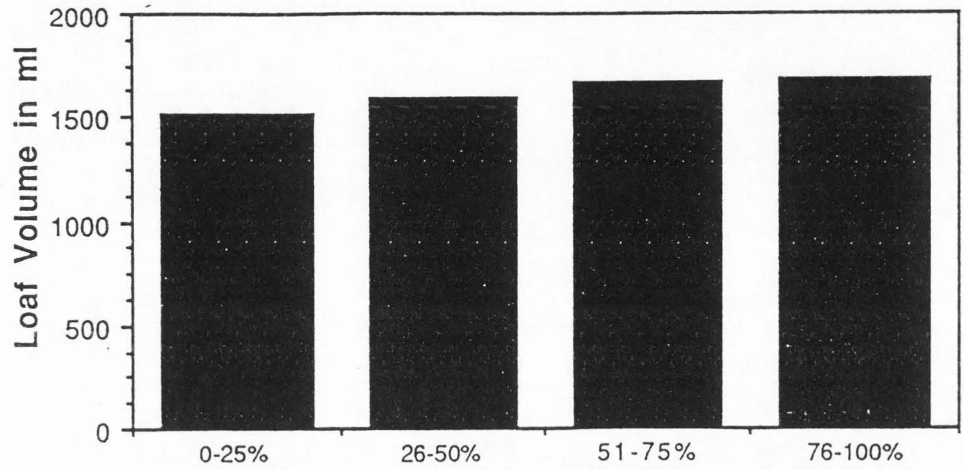

Fig. 4a--Relationship of samples grouped by age to loaf volume

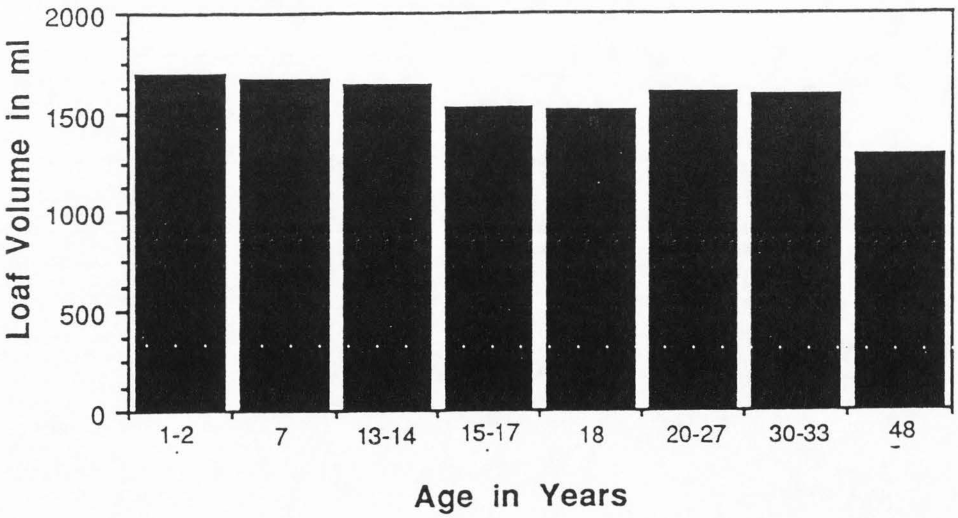

Fig. 4b--Percent of kernels that germinated compared to loaf volume

Table 9--Analysis of variance on chemical and physical characteristics based on samples grouped by age

Variable	DF	Mean Square	MSE	F Value	P
Aroma	7	.727	.499	1.46	.251
Bushel Weight	7	8.533	4.354	1.96	.126
Germinate	7	2905.	641.5	4.53	.006
Grade	7	2.941	1.21	2.43	.067
Sediment	7	142.6	68.53	2.08	.106
Loaf Vol	7	24680	32732	.75	.632
Gluten Ball	7	19137	29966	.64	.718
Protein	7	3.578	4.118	.87	.551

increase in germination rate from 26% to 50% resulted in 1589 ml average loaf volume. Samples in the 51% to 75% group had an average loaf volume of 1670 ml. Average loaf volumes of samples with over 76% germination climbed to 1685 ml. Grouped germination rate and aroma values were significantly related (P = .042).

Death of the kernel, as indicated by the inability to germinate, was associated with the quality of the bread (Table 10). Intensity of both rancid and stale increased as germination decreased (Fig. 5a); however, the correlations (-.417 and -.493, respectively) were low. Nutty scores increased as percent germination increased, but these scores were not statistically significant (Fig. 5b). Overall,

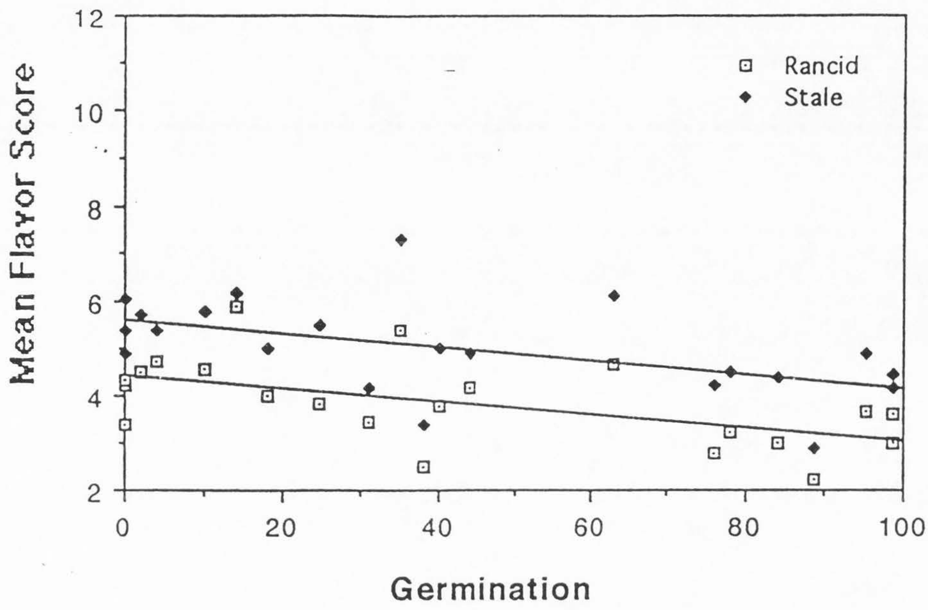

Fig. 5a--Percent of kernels that germinated compared to rancid and stale scores

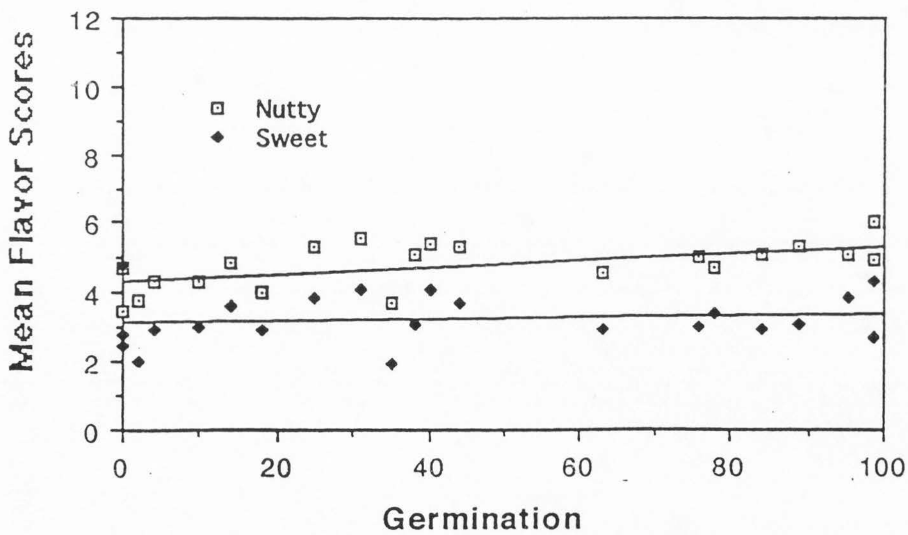

Fig. 5b--Percent of kernels that germinated compared to nutty and sweet scores

Table 10--Analysis of variance of aroma, bushel weight, grade, rancid, stale, nutty, and sweet by germination

Variable	DF	Mean Square	MSE	F Value	P
Aroma	3	4.32	.44	3.29	.042
Bushel Weight	3	54.53	18.19	4.86	.011
Grade	3	3.61	1.45	2.50	.089
Rancid	3	2.22	.60	3.71	.031
Stale	3	2.37	.76	3.12	.052
Nutty	3	.78	.36	2.19	.125
Sweet	3	.66	.51	1.32	.300

bread volume in samples with poorer germination rates was acceptable, but flavor was inferior. Apparently, deterioration in germination rate had more effect on fats affecting flavor than on proteins related to volume and components of wheat related to texture.

Grade

Full details on the statistical analysis of sample by grade can be found in Tables A.12, A.13, A.14, and A.15. Germination rates increased (P = .174) as grade quality increased (lower numbers) (Fig. 6). However, correlation between grade and germination rates (-.382) was low, possibly because grouped by age the oldest and the newest samples had the lowest or best grades. Viability dropped dramatically after grades one and two, even though broken and damaged kernels were removed before germination tests

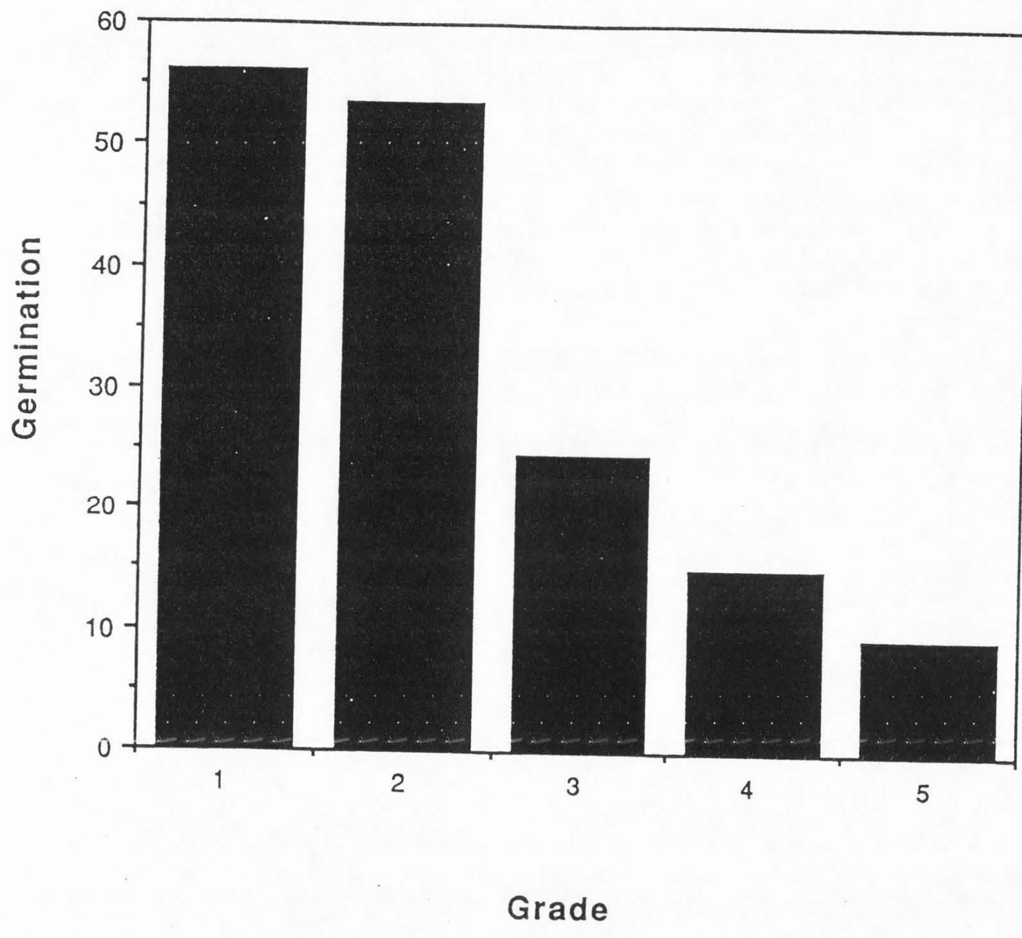

Fig. 6--Relationship of grade to percent of kernels that germinated

were made. Rough treatment of the wheat that decreases grade may have caused damage that was not visible to the eye. Loaf volumes were significantly different when grouped by grade, as were grain, porosity, crumbly, adhesive, and yeasty attributes, but none of these qualities were linear (Tables A.12, A.13, A.14).

Aroma

Scores on the aroma test, which was smelling the samples under ambient conditions and assigning scores from 1 to 6 with higher scores being given to the more objectionable odors, were related to both germination and grade. As germination rates decreased, the samples developed objectionable odors ($P = .042$). Grade and aroma were related at the .407 level with the samples having poor grades also having an off-smell.

Rancid and stale were the most important sensory scores. Wheat samples with a rancid aroma produced bread that received higher rancid ($R = .541$) and/or stale ($R = .432$) ratings (Fig. 7). Porosity and crumbly characteristics of the wheat were statistically related to aroma scores (Table A.16); however, the values could be misleading because means are random rather than directional, and there is a single sample of wheat in the last group.

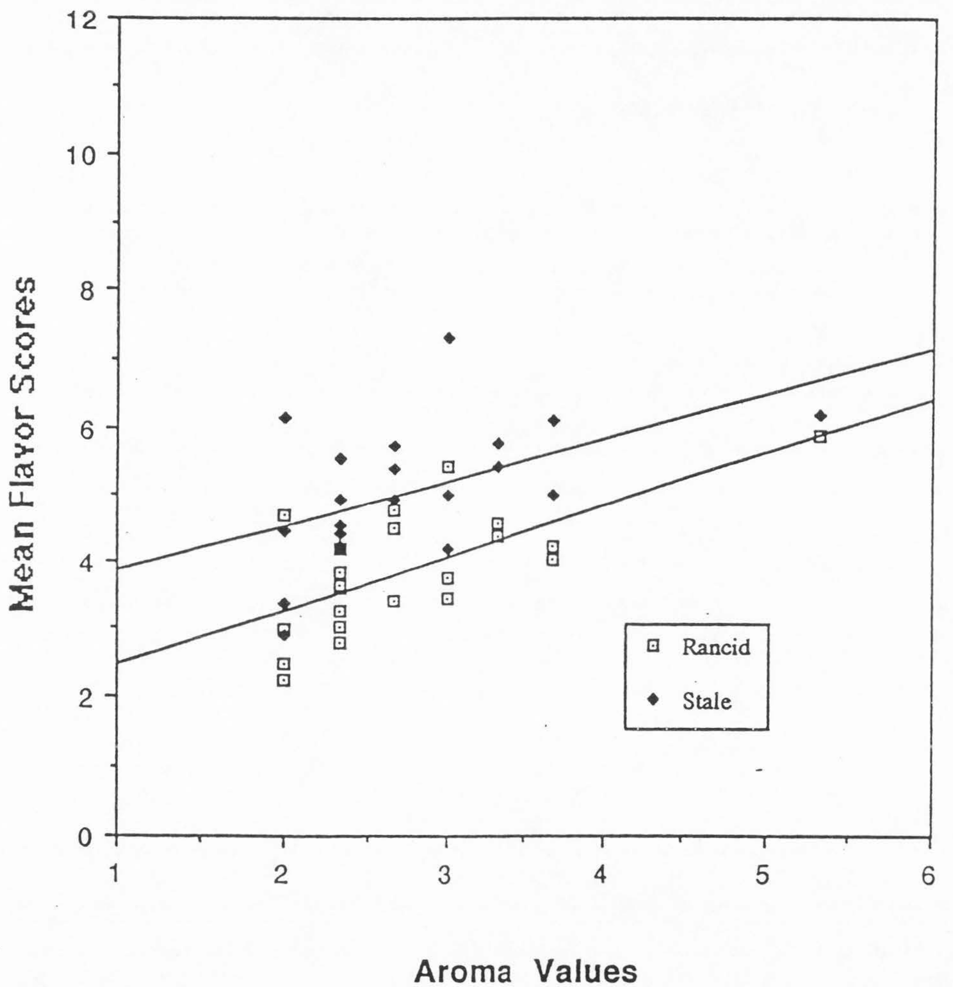

Fig. 7--Aroma values compared to rancid and stale scores

Weight per Bushel

Weight per bushel was one factor that helped determine grade. Wheat with higher weight per bushel did not produce bread with better loaf volume. Lowest weight per bushel group had the highest loaf volume, but volumes were not significantly different ($P = .680$).

Weight per bushel and sensory scores were somewhat related. Rancid ($R = -.426$) and stale ($R = -.410$) flavor properties of the bread decreased slightly as weight per bushel increased (Fig. 8a), but differences were not statistically significant (Table 11). Nutty ($R = .586$) and sweet ($R = .482$) increased as weight per bushel increased (Fig. 8b) ($P = .006$ and $P = .105$, respectively). The flavor scores support the desirability of buying wheat with a high weight per bushel for storage purposes.

Gluten Ball Volume, Sedimentation, and Loaf Volume as Related to Protein and Wheat Quality

Protein was tested by both Kjeldahl and NIR ($R = .88$). After protein quantity was tested, gluten balls were made and evaluated to see if they would indicate protein quality. Protein quality is connected to functional properties such as ability to form gluten, which is especially important to bread volume. In the controls and most samples, gluten formed a strong, large, cohesive ball. However, the gluten

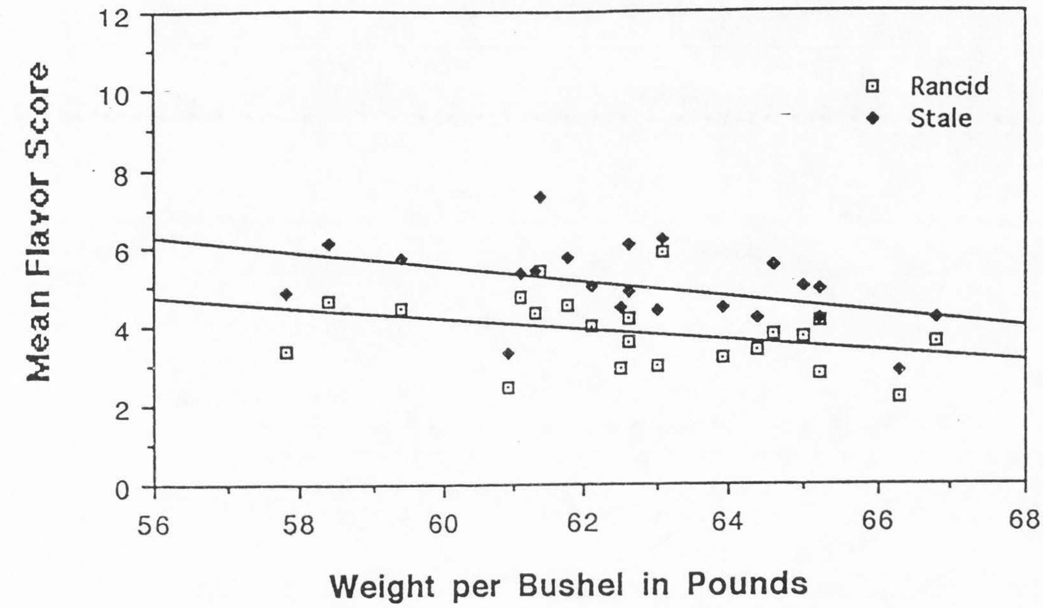

Fig. 8a--Relationship of weight per bushel to rancid and stale scores

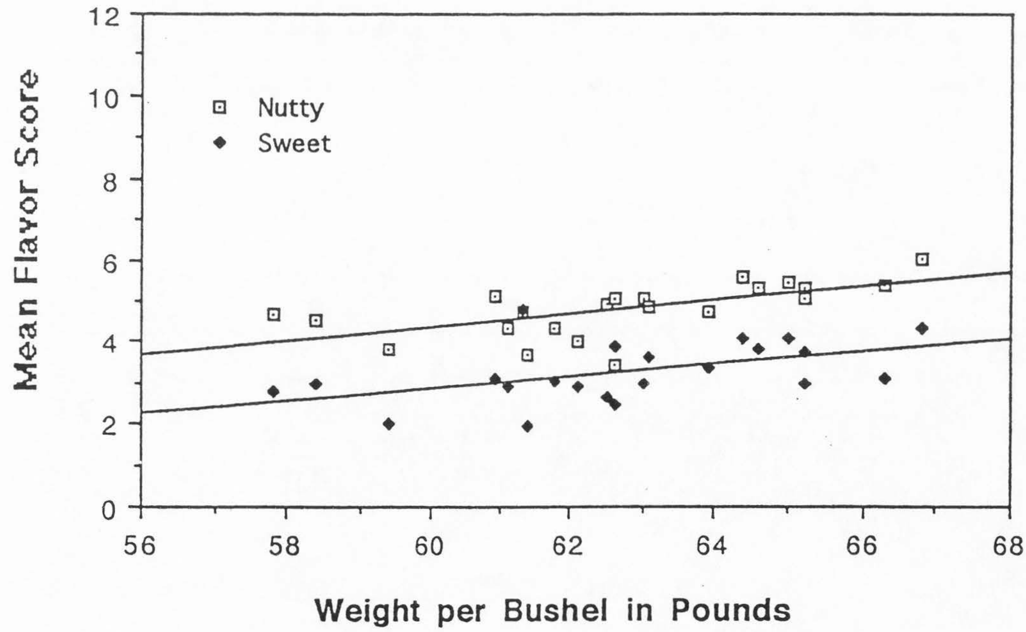

Fig. 8b--Relationship of weight per bushel to nutty and sweet scores

Table 11--Analysis of variance of aroma, grade, age, and nutty by weight per bushel

Variable	DF	Mean Square	MSE	F Value	P
Rancid	3	.946	.812	1.16	.351
Stale	3	1.478	.910	1.62	.219
Nutty	3	1.431	.248	5.77	.006
Sweet	3	1.048	.443	2.37	.105

had deteriorated in some of the older samples. When the gluten was washed for samples 15, 21, and 24, the gluten acted like foamy cottage cheese. Gluten did not adhere to itself, and the gluten ball volume was small (Table 5). Even if increased gluten ball volume did relate to increased bread volume (Fig. 9), the correlation coefficient was only .265 due to the great diversity among samples.

The gluten ball test is usually replaced by the simpler, less time-consuming sedimentation test. Sedimentation values of the wheat samples were low. Only one sample had a sedimentation value above 50, the preferred range for bread wheat. Two samples had sedimentation values in the 40 to 59 range, which indicates good gluten quality. Twenty-one wheat samples fell in the 20 to 39, range which is usually used for all purpose flour. Because only six samples were below 12% protein, low percent protein is not the only reason the sedimentation values were low. Perhaps the wheat had suffered damage in storage or the homemakers were not purchasing the best quality wheat. Sensory scores

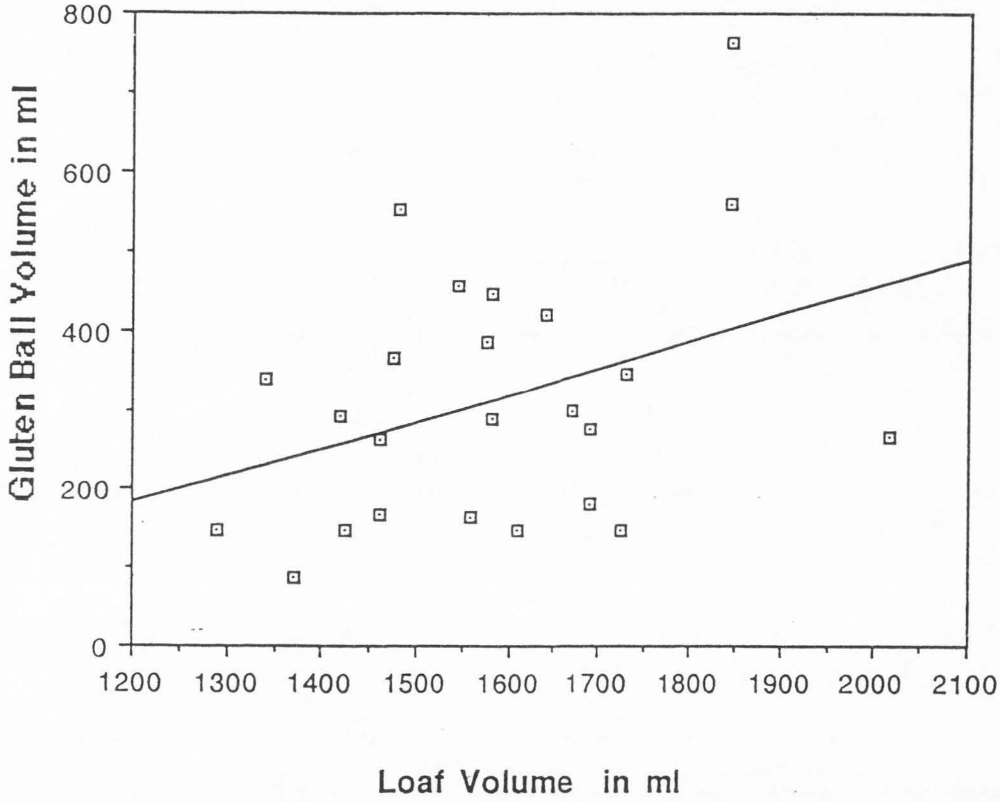

Fig. 9--Relationship of gluten ball volume to loaf volume

significantly related to sedimentation were not linear. Protein and gluten ball volume were the most important physical or chemical traits when samples were grouped by sedimentation values (P = .012 and P = .005, respectively).

Both gluten ball volume and sedimentation values increased linearly with percent protein increase (R = .571 and R = .738, respectively), but loaf volume did not (R = .076) (Table 12). Finney and Barmore (1948) decided that protein content is the major factor to account for variation in loaf volume within a single variety. They found that the relationship between protein and loaf volume was linear within a single variety. The present study did not agree with Finney and Barmore's findings because several different cultivars were tested and storage conditions were by the nature of the study not held constant. Quantity and quality of protein are influenced by both genetic and environmental factors (Quisenberry and Reitz, 1967). Loaf volumes increased with increased protein content in the first three protein groups but dropped off in the fourth group (Fig. 10). One sample in the above 15% protein group was the new control, which had not had time for post harvest maturation, which would have increased loaf volume. Loaf volume is determined not only by the quantity but also by the quality of the protein present in the wheat.

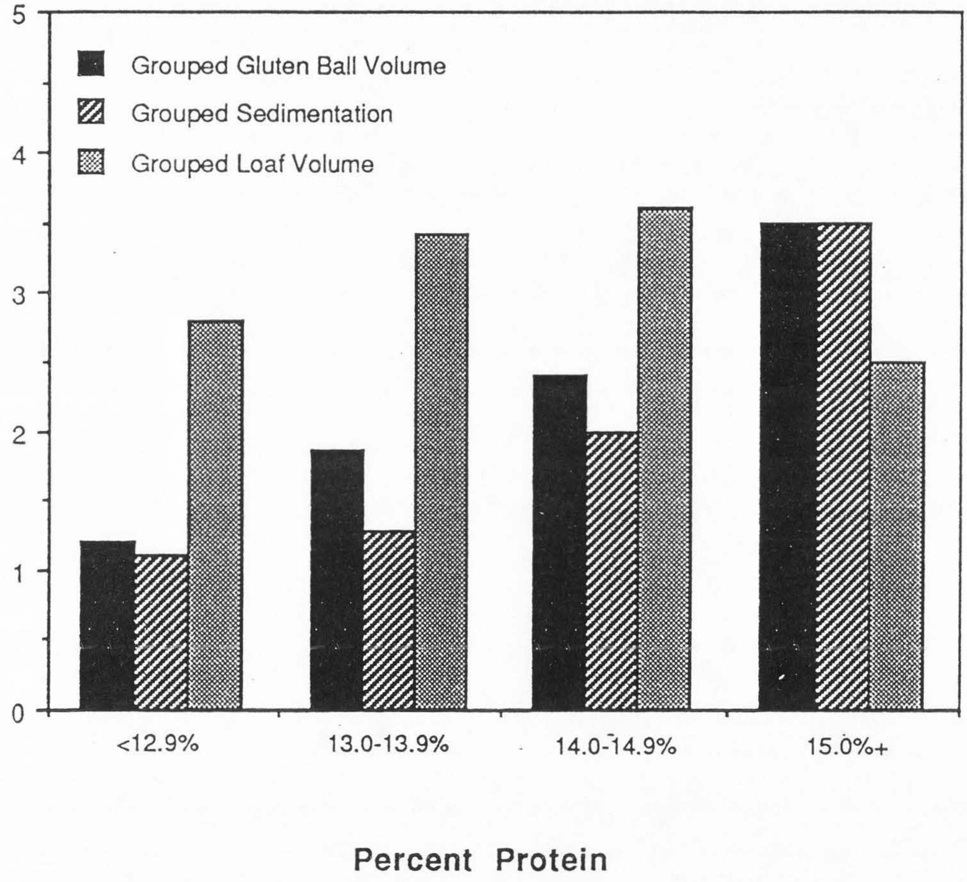

Fig. 10--Relationship of gluten ball volumes, sedimentation values, and loaf volumes to percent protein

Table 12--Analysis of variance on sediment, gluten ball volume, and loaf volume by protein content

Dependent Variable	DF	Mean Square	MSE	F Value	P
Sediment	3	443.	38.32	11.56	.0001
Gluten Ball	3	65092.	20907	3.11	.049
Loaf Vol	3	33646.	29777	1.13	.316

Even if loaf volume was not as closely related to protein, sedimentation, and gluten ball volume as expected, loaf volume was related to some sensory traits (Table 13).

Texture and Flavor Characteristics

Many sensory characteristics correlated negatively or positively with other sensory characteristics (Table 14). Bread with a coarse grain tended to be porous and crumbly bread (Fig. 11a). Coarse grain bread had lower bitter scores. Porous bread was crumbly (Fig. 11b) but not adhesive, gummy, chewy, or moist. Adhesive bread was chewy

Table 13--Analysis of variance on selected sensory characteristics by loaf volume

Variable	DF	Mean Square	MSE	F Value	P
Porosity	4	4.282	2.267	1.89	.159
Gummy	4	2.816	1.140	2.47	.084
Adhesive	4	1.073	.5984	1.79	.176
Rancid	4	1.075	.7736	1.39	.279
Nutty	4	.0464	.5045	.09	.984
Bitter	4	.5204	.3846	1.35	.291
Astringent	4	.7131	.4349	1.64	.210

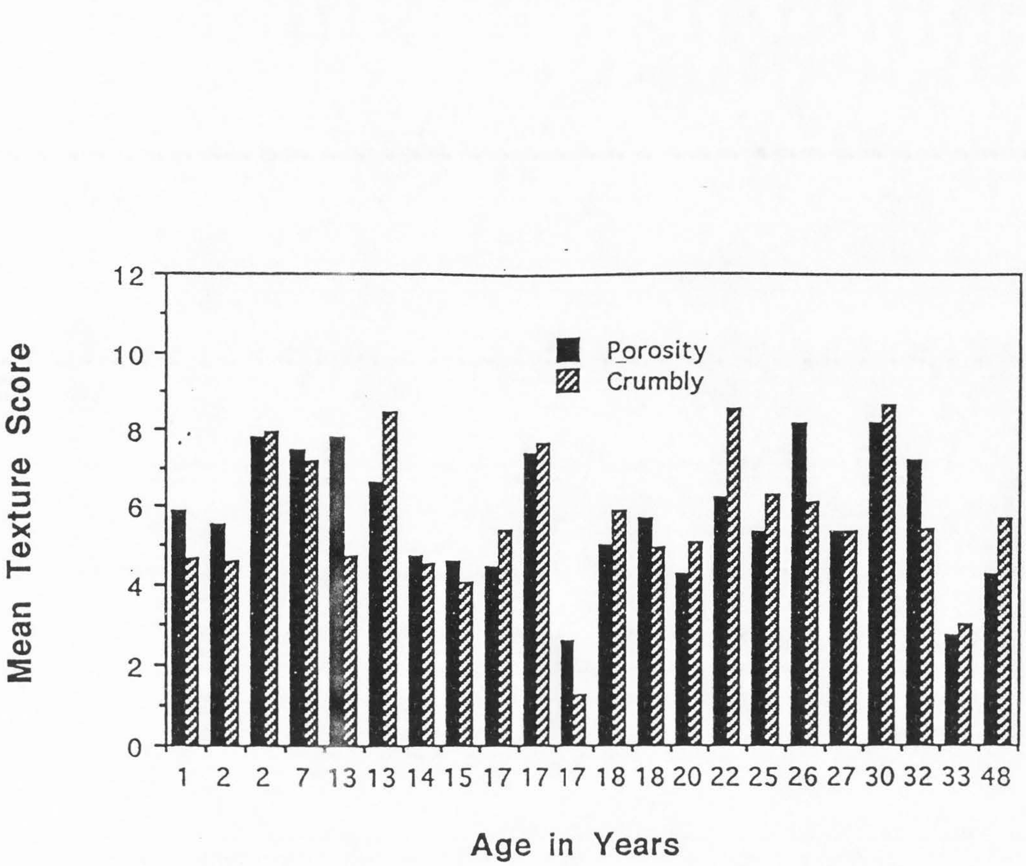

Fig. 11a--Relationship of mean porosity and crumbliness scores with samples identified by age

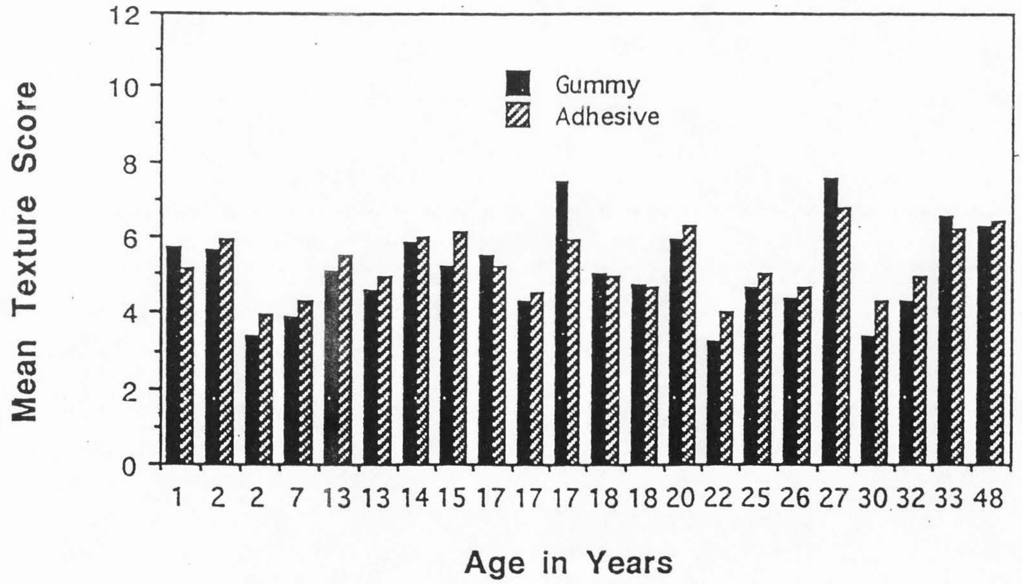

Fig. 11b--Relationship of mean gummy and adhesive scores with samples identified by age

Table 14--Correlation above +.500 for sensory characteristics

Sensory Values		**Correlation**
Porosity	Grain	.643
Crumbly	Grain	.566
Gummy	Grain	-.554
Yeasty	Grain	-.545
Crumbly	Porosity	.708
Gummy	Porosity	-.513
Adhesive	Porosity	-.691
Chewy	Porosity	-.745
Moist	Porosity	-.721
Adhesive	Crumbly	-.711
Chewy	Crumbly	-.865
Moist	Crumbly	-.839
Yeasty	Gummy	.590
Chewy	Adhesive	.808
Moist	Adhesive	.808
Moist	Chewy	.896
Stale	Rancid	.819
Bitter	Rancid	.829
Astringent	Rancid	.719
Nutty	Stale	-.666
Bitter	Stale	.720

(table continued)

Astringent	Stale	.901
Sweet	Nutty	.712
Astringent	Nutty	-.611
Sweet	Salty	.655
Astringent	Bitter	.715

and moist. Chewy bread was moist. Rancid bread was also considered stale, bitter, and astringent. Stale bread was not nutty, but it was bitter and astringent. Nutty bread was sweet but not astringent. Salty bread was sweet. Bitter bread tended to be astringent.

Storage Temperature and Conditions

Storage temperature had a limited effect on bread quality. No measured characteristics were correlated closely with storage conditions and temperature. Gluten ball volume and sediment were the only physical or chemical characteristics that were statistically significant. None of the sensory scores showed any pattern based on storage temperature and conditions (Fig. 12). Wheat stored under the various conditions was still alive and viable. Sweet ratings were slightly higher in the basement-stored samples possibly because of a decrease in sugar content by samples held at higher temperature due to their increased respiration rate. Only three samples were stored in permeable containers. Because sample 21 had

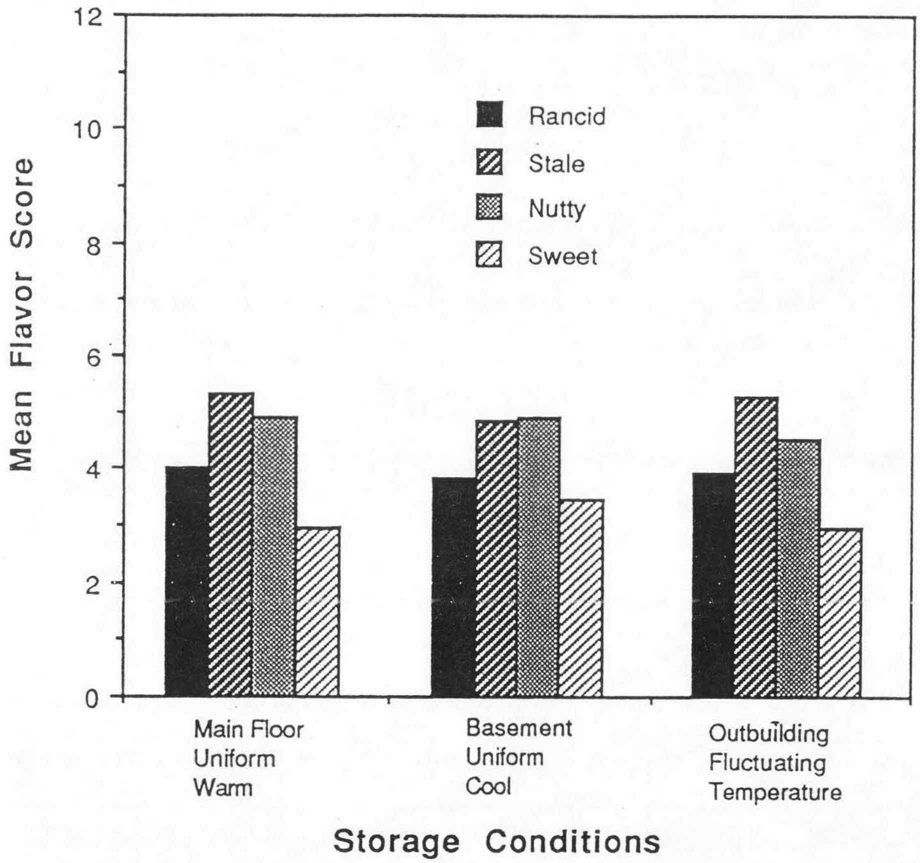

Fig. 12--Comparison of selected mean flavor scores by storage conditions

been treated with CCl_4, a carcinogen, it was not tasted, leaving only two samples which were stored in permeable containers with sensory scores. Some patterns can be observed (Fig. 13a and 13b), which might be meaningful in future studies with more samples in permeable containers. Grain, porosity, and crumbly were significantly lower in samples stored in permeable containers (Table A.35). Gummy, adhesive, chewy, and sensory moistness were significantly higher in wheat stored in permeable containers than in moistureproof containers. Germination averaged 44% for samples stored in moistureproof containers and only 6% for samples stored in permeable containers. Aroma and grade were higher, that is worse, in samples stored in permeable containers. Seed moisture content and storage temperature are major environmental factors affecting preservation of stored seeds, with seed moisture content commonly more important than temperature. Seeds acquire moisture equilibrium with the surrounding relative humidity. Seed moisture content can be controlled by storing dry seeds in sealed moistureproof containers (Bass, 1980). Waterproof or water-resistant containers are best for wheat storage (Bugbee, 1989b). Keeping in mind that more samples stored in permeable containers need to be studied, these data and previous research point out the advantages of storing wheat in moistureproof containers.

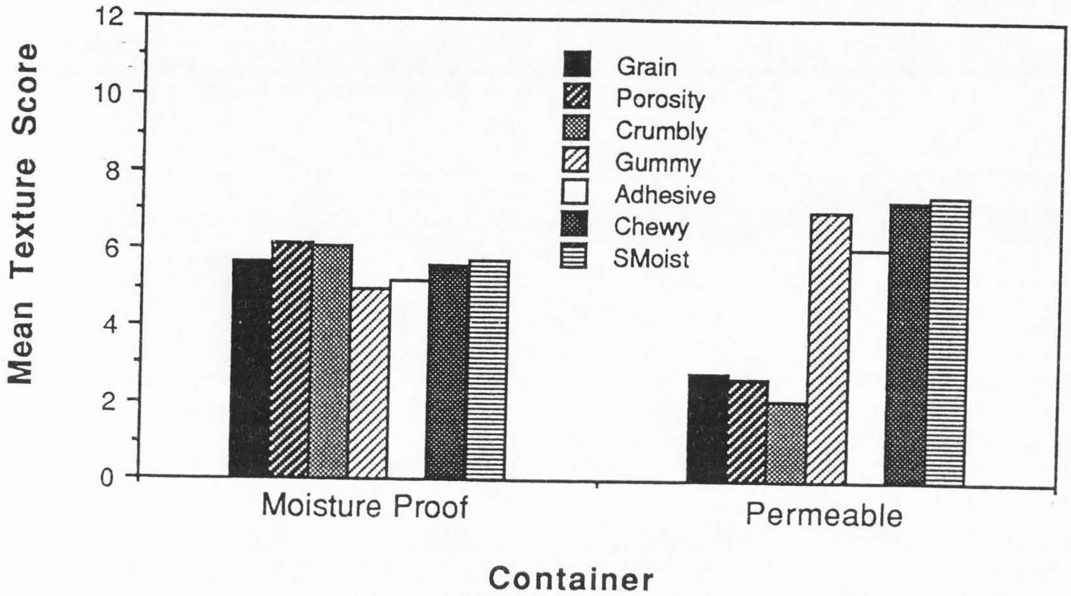

Fig. 13a--Comparison of mean texture scores by container type

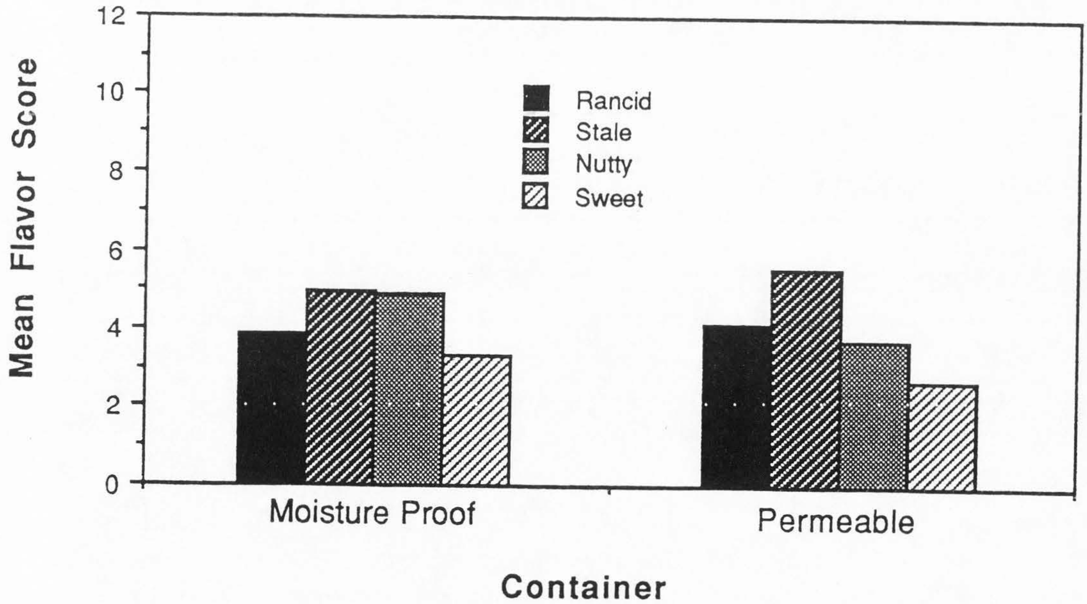

Fig. 13b--Comparison of selected mean flavor scores by container type

RECOMMENDATIONS

Wheat for storage should be of good quality and free from damaged kernels and foreign material. No one criterion was a perfect predictor of quality. A high percentage of germination was one of the better indicators of quality. Commercial buyers use grain grade and weight per bushel, a component of grade, to gauge quality. These data support the desirability of buying wheat with a high weight per bushel for storage purposes. Often when wheat is purchased for storage in the home, information on grade and weight per bushel is not available. A simple test not requiring sophisticated equipment for those who store wheat in their homes is the sniff test. Rancid aroma in wheat forecasted an off-flavor in bread. Quality is related to end use. Perhaps one bag could be purchased and made into bread or used in the manner the homemaker plans to use the wheat before large quantities of wheat are purchased. Only the amount of wheat that will be used in a reasonable time should be purchased. Wheat breeders are constantly improving varieties of wheat, and there is no point in storing large quantities of inferior wheat.

Seed moisture content and storage temperature are major factors affecting preservation of stored seeds, with seed moisture content commonly more important than temperature. Food grade, moisture-proof containers should be used and the wheat kept in a cool area to protect quality. Heavy plastic containers with tight, snap-on lids, tightly sealed heavy polyethylene bags, glass jars with rubber gaskets on lids, or metal cans with moisture-resistant seals are suitable. Containers should be off concrete floors on spacers or shelves. Sample 11, which was stored directly on the concrete, had high rancid, stale, bitter, and astringent scores and low nutty and sweet scores (Table A.3).

Once good quality wheat is purchased, it should be protected from insects and rodents. Respiration of insects may cause buildup of moisture in addition to leaving undesirable exoskeletons and products of metabolism. Sample 17, which was heavily infested with insects and exoskeletons, made it undesirable. Nevertheless, toxic treatments should be avoided. The sample in this study treated with CCl_4, a carcinogen, was not tasted.

Storage temperatures and conditions were not closely related to any physical, chemical, or sensory properties recorded. In this study wheat stored in outbuildings with fluctuating temperatures compared favorably with wheat stored other places. Also, the cold temperatures might ameliorate insect infestation. After the initial post harvest improvement, wheat retains quality for some time. Many older samples made bread with fairly good volumes; however, flavor deteriorated in some samples. To minimize the length of storage, it is important to rotate wheat supply or use it before buying more.

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APPENDICES

APPENDIX A. TABLES

Table A.1-Correlations of chemical and physical tests and sensory scores

	Age	Temp	Aroma	Grade	Sediment	Protein	Bu Wt	Germinate
Temp	0.340							
Aroma	0.258	0.072						
Grade	0.506	0.272	0.407					
Sediment	-0.224	-0.011	0.226	-0.157				
Protein	-0.194	-0.011	-0.275	-0.084	0.738			
Bu Wt	-0.427	-0.302	0.062	-0.275	-0.040	-0.117		
Germinate	-0.564	-0.080	-0.571	-0.382	0.182	0.116	0.307	
Ball Vol	-0.167	0.052	-0.050	0.042	0.661	0.571	-0.153	0.052
Loaf Vol	-0.305	0.110	-0.219	0.025	0.228	0.076	-0.103	0.239
Grain	-0.060	-0.095	-0.159	-0.059	-0.093	0.074	-0.258	0.138
Porous	-0.203	0.058	-0.255	0.088	0.028	-0.138	-0.131	0.501
Crumbly	-0.002	0.065	-0.049	0.068	-0.320	-0.455	-0.233	0.231
Gummy	0.358	0.177	-0.064	0.250	0.196	0.216	-0.019	-0.100
Adhesive	0.123	-0.184	-0.031	-0.180	-0.060	0.312	0.190	-0.266
Chewy	0.060	-0.010	-0.063	-0.205	0.310	0.481	0.173	-0.268
Moisture	0.040	-0.047	0.006	-0.065	0.076	0.353	0.268	-0.218
Rancid	0.413	0.053	0.541	0.328	-0.338	-0.175	-0.426	-0.417
Stale	0.277	-0.013	0.432	0.130	-0.290	0.030	-0.410	-0.493
Nutty	-0.485	-0.265	-0.257	-0.516	-0.019	-0.383	0.586	0.479
Yeasty	0.401	0.339	0.079	0.440	-0.158	-0.322	-0.010	0.129
Salty	-0.033	-0.115	-0.007	-0.240	-0.602	-0.532	0.238	0.156
Sweet	-0.356	-0.141	0.163	-0.438	-0.303	-0.532	0.482	0.142
Bitter	0.324	0.219	0.369	0.137	-0.286	-0.172	-0.280	-0.205
Astring	0.077	-0.032	0.275	-0.002	-0.252	0.155	-0.270	-0.208

	Ball Vol	Loaf Vol	Grain	Porous	Crumbly	Gummy	Adhesive	Chewy
Loaf Vol	0.280							
Grain	-0.034	0.167						
Porous	0.226	0.515	0.643					
Crumbly	-0.209	0.165	0.566	0.708				
Gummy	0.048	-0.519	-0.554	-0.513	-0.461			
Adhesive	-0.089	-0.442	-0.203	-0.691	-0.711	0.433		
Chewy	-0.017	-0.295	-0.373	-0.745	-0.865	0.526	0.808	
Moisture	-0.090	-0.251	-0.473	-0.721	-0.839	0.578	0.808	0.896
Rancid	-0.046	-0.481	-0.010	-0.167	0.256	0.198	-0.085	-0.236
Stale	-0.015	-0.396	0.059	-0.293	0.072	-0.038	0.052	-0.085
Nutty	-0.110	0.167	-0.019	0.332	0.121	-0.216	-0.094	-0.150
Yeasty	-0.145	-0.331	-0.545	-0.139	0.022	0.590	-0.164	-0.137
Salty	-0.383	-0.389	-0.009	0.035	0.169	-0.136	0.075	-0.155
Sweet	-0.403	-0.129	-0.229	-0.104	-0.005	-0.163	0.087	0.049
Bitter	0.020	-0.438	-0.122	-0.076	0.167	0.252	-0.099	-0.213
Astring	-0.085	-0.367	0.106	-0.230	0.096	-0.032	0.059	-0.052

	Moisture	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter
Rancid	-0.211							
Stale	-0.116	0.819						
Nutty	-0.134	-0.498	-0.666					
Yeasty	-0.018	0.301	-0.073	-0.030				
Salty	-0.107	0.178	0.073	0.423	0.191			
Sweet	0.091	-0.142	-0.273	0.712	0.043	0.655		
Bitter	-0.114	0.829	0.720	-0.327	0.263	0.295	-0.055	
Astring	-0.042	0.719	0.901	-0.611	-0.150	0.109	-0.253	0.715

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Table A.2-Mean sensory scores for textural properties by individual sample

Sample	Yrs	Grain	Poros.	Crumbly	Gummy	Adhesive	Chewy	Moisture
1	1	5.31	4.79	4.09	6.19	5.61	6.53	5.24
2	2	4.93	5.54	4.63	5.62	5.91	6.46	5.92
3	2	6.58	7.8	7.88	3.40	3.97	4.76	5.39
4	7	6.57	7.42	7.16	3.91	4.34	4.82	4.69
5	13	5.93	7.77	4.76	5.07	5.48	6.01	6.52
6	13	6.45	6.62	8.47	4.61	4.97	5.07	5.2
7	14	3.82	4.79	4.55	5.83	6.02	6.53	6.91
8	15	3.42	4.64	4.12	5.25	6.13	5.77	6.67
9	17	3.82	4.51	5.42	5.50	5.25	5.70	5.73
10	17	6.62	7.40	7.62	4.33	4.51	4.08	4.65
11	17	2.52	2.61	1.27	7.50	5.90	8.07	8.07
12	18	4.78	5.71	4.96	4.71	4.67	5.90	6.06

Table A.2-Mean sensory scores for textural properties by individual sample (continued)

Sample	Yrs	Grain	Poros.	Crumbly	Gummy	Adhesive	Chewy	Moisture
13	18	4.90	5.00	5.89	5.00	4.96	6.13	6.33
14	20	4.22	4.29	5.07	5.92	6.30	6.29	6.69
15	22	5.97	6.26	8.53	3.24	4.00	4.25	3.96
16	25	5.51	5.38	6.32	4.63	4.99	4.97	5.13
18	26	7.30	8.14	6.08	4.38	4.67	5.20	5.18
19	27	4.78	5.71	4.96	4.71	4.67	5.90	6.06
20	30	7.23	8.14	8.56	3.39	4.29	4.76	4.98
22	32	5.41	7.14	5.46	4.32	4.97	5.59	5.00
23	33	3.16	2.77	3.05	6.59	6.23	6.56	6.58
24	48	6.98	4.32	5.70	6.31	6.39	7.18	6.49

Table A.3-Mean sensory scores for flavor characteristics by individual sample

Sample	Yrs	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
1	1	2.98	4.46	4.94	2.31	2.16	2.68	2.05	2.70
2	2	3.60	4.20	6.02	2.66	2.88	4.32	2.36	2.56
3	2	2.80	4.21	5.04	1.93	2.24	3.00	2.09	2.96
4	7	4.70	6.14	4.57	2.38	2.56	2.97	2.91	3.80
5	13	2.23	2.91	5.36	2.53	2.63	3.12	1.56	1.86
6	13	3.25	4.51	4.74	2.49	2.43	3.38	1.98	2.75
7	14	3.44	4.20	5.58	2.61	2.68	4.08	2.57	2.46
8	15	3.65	4.91	5.09	2.70	2.76	3.86	3.19	3.36
9	17	3.85	5.54	5.32	2.86	2.88	3.84	3.01	2.85
10	17	5.89	6.21	4.87	2.54	2.54	3.62	3.83	3.44
11	17	4.23	6.10	3.47	2.41	2.1	2.45	3.34	4.03

Table A.3-Mean sensory scores for flavor characteristics by individual sample (continued)

Sample	Yrs	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
12	18	2.49	3.38	5.13	2.20	2.02	3.10	1.41	1.40
13	18	4.37	5.40	4.76	3.01	2.96	4.82	3.15	3.21
14	20	3.76	5.00	5.42	2.67	2.60	4.08	2.85	3.05
15	22	4.58	5.78	4.36	2.24	2.74	3.02	2.84	3.66
16	25	5.40	7.31	3.70	2.78	2.45	1.93	3.63	4.38
18	26	3.03	4.43	5.08	2.69	2.75	2.98	2.85	2.67
19	27	4.50	5.74	3.81	2.35	2.42	1.98	3.22	3.49
20	30	4.18	4.93	5.13	2.50	2.86	3.73	2.48	2.7
22	32	3.41	4.92	4.69	2.16	2.32	2.80	2.54	2.3
23	33	4.02	5.01	4.00	2.45	2.44	2.93	1.86	2.46
24	48	4.76	5.39	4.33	2.29	2.47	2.95	2.75	3.33

Sample 17 was not tasted because it was infested with many insects. Sample 21 was not tasted because it had been treated with CCl_4, a carcinogen.

Table A.4-Mean QDA scores for texture grouped in years

Age in Years	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
1-2	5.73	6.42	5.74	4.91	5.01	5.75	5.55
7	6.57	7.42	7.16	3.91	4.34	4.82	4.69
13-14	4.90	5.96	5.48	5.19	5.65	5.84	6.28
15-17	4.53	5.05	5.03	5.41	5.06	5.98	6.17
18	5.10	5.28	6.80	4.58	5.15	5.27	5.32
20-27	6.50	6.29	5.92	5.53	5.48	5.54	5.80
30-33	5.27	6.02	5.69	4.77	5.16	5.63	5.61
48	6.98	4.32	5.70	6.31	6.39	7.18	6.49
LSD	NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.5-Mean QDA scores for flavor grouped in years

Age in Years	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
1-2	3.13	4.29	5.33	2.30	2.43	3.33	2.17	2.74
7	4.70	6.14	4.57	2.38	2.56	2.97	2.91	3.80
13-14	3.14	4.13	5.19	2.58	2.63	3.61	2.32	2.60
15-17	4.16	5.33	4.71	2.60	2.50	3.57	2.94	2.99
18	4.17	5.39	4.89	2.45	2.67	3.55	2.84	3.35
20-27	4.31	5.83	4.20	2.61	2.54	2.30	3.23	3.51
30-33	3.87	4.95	4.66	2.97	2.54	3.15	2.29	2.48
48	4.76	5.39	4.33	2.29	2.47	2.95	2.75	3.33
LSD	NS	NS	NS	NS	NS	NS	NS	NS

Table A.6-Means of physical and chemical tests grouped by years

Age in Years	N	Aroma	Grade	Bushel Weight	Germinate	Protein	Sediment	Loaf Vol	Gluten Ball
1-2	3	2.20	1.33[b]	65.27	91.1[a]	14.96	46.0[a]	1690	402
7	1	2.00	2.00[ab]	58.40	63.0[abc]	13.73	23.0[b]	1670	299
13-14	4	2.41	1.75[ab]	64.30	73.2[ab]	12.96	27.5[b]	1642	259
15-17	5	3.47	2.40[ab]	62.50	15.4[cd]	13.84	30.0[ab]	1523	378
18	2	3.17	2.00[ab]	63.35	25.0[bcd]	10.77	22.5[b]	1510	164
20-27	4	2.58	3.25[ab]	61.45	30.5[bcd]	12.98	28.5[ab]	1605	305
30-33	4	3.00	4.00[a]	62.10	15.5[cd]	13.44	32.5[ab]	1591	348
48	1	2.67	1.00[b]	61.10	4.0[d]	14.58	35.0[ab]	1290	145
LSD		NS	2.27	NS	52.21	NS	NS (P=.106)	NS	NS

Numbers with different superscripts are significantly different.

Table A.7-Analysis of variance on physical, chemical, and sensory characteristics grouped by age

Variable	DF	Mean Square	MSE	F Value	P
Aroma	7	.727	.499	1.46	.251
Bushel Weight	7	8.534	4.354	1.96	.126
Germination	7	2905.	641.5	4.53	.006
Grade	7	2.942	1.210	2.43	.067
Sediment	7	142.6	68.530	2.08	.106
Loaf Vol	7	24680.	32733	.75	.632
Gluten Ball	7	19137.	29966	.64	.718
Protein	7	3.578	4.118	.87	.551
Grain	7	1.832	2.057	.89	.539
Porosity	7	1.471	3.241	.45	.852
Crumbly	7	1.019	4.467	.23	.972
Gummy	7	.701	1.838	.38	.898
Adhesive	7	.475	.796	.60	.749
Chewy	7	.548	1.122	.49	.828
Moist	7	.572	1.219	.47	.842
Rancid	7	.922	.786	1.17	.377
Stale	7	1.264	.855	1.48	.253
Nutty	7	.421	.416	1.01	.463
Yeasty	7	.121	.246	.49	.842
Salty	7	.016	.097	.17	.988
Sweet	7	.592	.498	1.19	.370
Bitter	7	.446	.393	1.14	.396
Astringent	7	.484	.490	.99	.478

Table A.8-Mean QDA scores for texture grouped by germination rate

Germinate	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
0-25%	11	5.10	5.12	5.26	5.56	5.41	5.97	5.99
26-50%	4	5.14	5.52	6.08	4.95	5.31	5.73	6.01
51-75%	2	6.57	7.42	7.16	3.91	4.34	4.82	4.69
76-100%	4	5.76	6.63	5.81	4.86	5.18	5.61	5.72
LSD	4	NS	NS	NS	NS	NS	NS	NS

Table A.9-Mean QDA scores for flavor grouped by germination rate

Germinate	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
0-25%	4.19^{ab}	5.34^{ab}	4.44	2.59	2.44	2.96	2.76	3.00
26-50%	4.23^{ab}	5.37^{ab}	4.95	2.71	2.71	3.73	2.94	3.16
51-75%	4.70^{a}	6.14^{a}	4.57	2.38	2.56	2.97	2.91	3.80
76-100%	3.07^{b}	4.23^{b}	5.18	2.71	2.55	3.33	2.30	2.69
LSD	1.39	1.56	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.10-Means of physical and chemical tests grouped by germination rate

Germinate	Aroma	Grade	Bushel Weight	Gluten Ball	Loaf Vol	Sediment	Protein
0-25%	3.15	3.18	61.7^{ab}	316	1510	31	13.5
25-50%	2.93	2.00	63.4^{a}	272	1589	27	12.6
51-75%	2.00	2.00	58.4^{b}	299	1670	23	13.7
76-100%	2.24	1.71	65.5^{a}	341	1685	35	13.8
LSD	NS	NS	3.42	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.11-Analysis of variance on physical, chemical, and sensory characteristics grouped by germination rate

Variable	DF	Mean Square	MSE	F Value	P
Aroma	3	4.32	.44	3.29	.042
Bushel Weight	3	54.53	18.19	4.86	.011
Grade	3	3.63	1.45	2.50	.089
Sediment	3	96.47	90.28	1.07	.385
Loaf Vol	3	46388	27867	1.66	.206
Gluten Ball	3	4722	29962	.16	.923
Protein	3	1.62	4.304	.38	.771
Grain	3	1.13	2.124	.53	.666
Porosity	3	4.02	2.424	1.66	.212
Crumbly	3	1.55	3.613	.43	.735
Gummy	3	1.28	1.280	.86	.480
Adhesive	3	.37	.369	.50	.689
Chewy	3	.48	.482	.48	.701
Moist	3	.59	.587	.55	.656
Rancid	3	2.22	2.224	3.71	.031
Stale	3	2.37	2.374	3.12	.052
Nutty	3	.78	.781	2.19	.125
Yeasty	3	.07	.070	.31	.820
Salty	3	.08	.081	1.81	.345
Sweet	3	1.05	1.047	2.37	.105
Bitter	3	.48	.482	1.21	.334
Astringent	3	.47	.469	.96	.435

Table A.12-Means of QDA texture scores grouped by grade

Grade	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
1	7	4.70	4.86[ab]	4.89[ab]	5.73	5.88[ab]	6.28	6.25
2	7	6.01	6.58[a]	6.68[b]	4.37	4.65[b]	5.26	5.40
3	4	4.96	5.94[a]	5.00[ab]	5.03	5.09[ab]	5.98	5.88
4	4	6.84	6.96[a]	7.18[a]	5.10	4.65[b]	5.08	5.57
5	2	3.16	2.77[b]	3.05[b]	6.59	6.23[a]	6.56	6.85
LSD		NS	2.50	2.89	NS	1.26	NS	NS

Numbers with different superscripts are significantly different.

Table A.13-Means of QDA flavor scores grouped by grade

Grade	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
1	3.72	4.81	5.24	2.58[b]	2.64	3.69	2.68	2.90
2	3.72	5.05	4.71	2.50[b]	2.49	3.17	2.57	3.02
3	3.61	4.93	4.47	2.34[b]	2.45	2.84	2.57	2.96
4	4.86	5.62	4.66	2.46[b]	2.61	3.11	3.18	3.21
5	4.02	5.01	4.00	4.25[a]	2.44	2.93	1.86	2.46
LSD	NS	NS	NS	.48	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.14-Means of chemical and physical tests grouped by grade

Grade	Aroma	Germinate	Bushel Weight	Sediment	Loaf Vol	Gluten Ball	Protein
1	2.52	56.06	63.8	33.14	1454[b]	270	13.23
2	2.57	53.43	62.2	27.71	1678[ab]	300	12.93
3	2.92	24.68	62.1	36.00	1699[a]	486	15.03
4	3.24	15.00	62.8	28.25	1529[ab]	294	13.56
5	3.34	9.50	62.0	30.00	1592[ab]	204	11.95
LSD	NS	NS	NS	NS	232	NS	NS

Numbers with different superscripts are significantly different.

Table A.15-Analysis of variance on physical, chemical, and sensory characteristics grouped by grade

Variable	DF	Mean Square	MSE	F Value	P
Aroma	4	.584	.565	1.03	.416
Bushel Weight	4	3.342	6.107	.55	.703
Germinate	4	2089.	1170.	1.78	.174
Sediment	4	59.980	97.630	.61	.658
Loaf Vol	4	61117.	23790.	2.57	.071
Gluten Ball	4	39783.	23910.	1.66	.200
Protein	4	4.155	3.912	1.06	.402
Grain	4	4.533	1.381	3.28	.036
Porosity	4	5.950	1.875	3.17	.040
Crumbly	4	6.722	2.516	2.67	.069
Gummy	4	2.174	1.291	1.68	.200
Adhesive	4	1.580	.479	3.30	.036
Chewy	4	1.447	.809	1.79	.178
Moist	4	.942	1.016	.93	.472
Rancid	4	.881	.819	1.07	.400
Stale	4	.360	1.140	.32	.863
Nutty	4	.638	.365	1.75	.186
Yeasty	4	.779	.069	11.30	.0001
Salty	4	.034	.078	.44	.779
Sweet	4	.548	.525	1.04	.413
Bitter	4	.382	.417	.92	.477
Astringent	4	.122	.574	.21	.928

Table A.16-Means of QDA texture scores grouped by aroma

Aroma	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
2.00	4	6.22^{a}	6.61^{ab}	5.50^{a}	5.56	5.44	5.83^{ab}	5.91
2.33	7	5.67^{a}	6.48^{ab}	6.45^{a}	4.59	5.03	5.39^{bc}	5.56
2.67	3	5.72^{a}	5.72^{ab}	5.37^{a}	5.11	5.34	6.22^{ab}	5.85
3.00	4	4.52^{ab}	4.82^{bc}	5.31^{a}	5.46	5.77	5.93^{ab}	6.24
3.33	3	5.44^{a}	5.63^{ab}	7.21^{a}	4.12	4.48	5.19^{bc}	5.14
3.67	2	2.84^{b}	2.69^{c}	2.16^{b}	7.04	6.06	7.32^{a}	7.46
5.33	1	6.62^{a}	7.40^{a}	7.62^{a}	4.33	4.51	4.08^{c}	4.65
LSD		2.37	2.57	2.89	NS	NS	1.59	NS

Numbers with different superscripts are significantly different.

Table A.17-Means of QDA flavor scores grouped by aroma

Aroma	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
2.00	3.60	4.81	4.67^{ab}	2.39	2.44^{ab}	2.69	2.44	2.96
2.33	3.48	4.68	5.23^{a}	2.55	2.68^{ab}	3.59	2.56	2.84
2.67	3.55	4.56	4.72^{ab}	2.22	2.27^{b}	2.95	2.23	2.34
3.00	4.20	5.50	4.90^{a}	2.69	2.58^{ab}	3.36	3.02	3.30
3.33	4.48	5.59	4.56^{ab}	2.63	2.85^{a}	3.92	3.00	3.44
3.67	4.13	5.56	3.74^{b}	3.33	2.27^{b}	2.69	2.60	3.24
5.33	5.89	6.21	4.87^{ab}	2.54	2.54^{ab}	3.62	3.83	3.44
LSD	NS	NS	1.15	NS	.44	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.18-Means of chemical and physical tests grouped by aroma

Aroma	Grade	Germinate	Bushel Weight	Gluten Ball	Protein	Loaf Vol	Sediment
2.00	2.50	63.10^{ab}	61.65	445	15.09^{a}	1618	37.2
2.33	1.86	71.53^{a}	64.67	270	12.93^{ab}	1643	28.8
2.67	2.00	1.33^{c}	60.07	401	13.55^{ab}	1518	37.3
3.00	2.25	26.75^{abc}	63.20	220	11.47^{b}	1562	26.8
3.33	3.00	16.00^{bc}	61.93	199	12.93^{b}	1553	24.0
3.67	4.00	9.00^{c}	62.35	360	15.67^{a}	1502	35.5
5.33	4.00	14.00^{c}	63.10	448	13.94^{ab}	1580	30.0
LSD	NS	50.22	NS	NS	1.51	NS	NS

Numbers with different superscripts are significantly different.

Table A.19-Analysis of variance on physical, chemical, and sensory characteristics grouped by aroma

Variable	DF	Mean Square	MSE	F Value	P
Loaf Vol	6	9941.	37461.	.27	.946
Gluten Ball	6	33675.	24197.	1.39	.274
Protein	6	6.544	3.040	2.15	.100
Grain	6	3.409	1.411	2.42	.078
Porosity	6	5.127	1.660	3.09	.036
Crumbly	6	6.366	2.098	3.03	.039
Gummy	6	2.187	1.168	1.87	.152
Adhesive	6	.730	.673	1.08	.415
Chewy	6	1.670	.635	2.63	.060
Moist	6	1.445	.826	1.75	.178
Rancid	6	1.153	.702	1.64	.203
Stale	6	.827	1.057	.78	.596
Nutty	6	.623	.331	1.91	.145
Yeasty	6	.284	.172	1.65	.201
Salty	6	.124	.048	2.58	.064
Sweet	6	.672	.472	1.42	.270
Bitter	6	.466	.389	1.20	.359
Astringent	6	.466	.389	1.20	.360

Table A.20-Means of texture scores compared by weight per bushel

Bushel Weight	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
<60.0	3	6.22	6.63	5.99	5.27	5.36	5.62	5.60
60.0-61.9	5	5.62	5.33	6.28	4.78	5.00	5.68	5.59
62.0-63.9	9	5.02	5.44	5.05	5.48	5.36	5.83	5.97
64.0+	7	5.22	6.12	5.84	4.96	5.32	5.79	6.02
LSD		NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.21-Means of flavor scores compared by weight per bushel

Bushel Weight	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
<60.0	4.20	5.60	4.36[b]	2.30	2.43	2.58[b]	2.89	3.20
60.0-61.9	4.32	5.45	4.46[b]	2.50	2.53	3.16[ab]	2.76	3.20
62.0-63.9	3.86	5.09	4.60[b]	2.77	2.45	3.13[ab]	2.73	3.06
64+	3.40	4.43	5.44[a]	2.54	2.68	3.74[a]	2.42	2.63
LSD	NS	NS	.67	NS	NS	.89	NS	NS

Numbers with different superscripts are significantly different.

Table A.22-Means of physical and chemical tests grouped in bushel weight

Bushel Weight	Aroma	Germinate	Grade	Gluten Ball	Loaf Vol	Protein	Sediment
<60.0	2.22	21.6	3.0	476	1663	14.39	30.7
60.0-61.9	3.00	17.4	2.0	274	1528	13.31	29.2
62.0-63.9	3.11	43.2	3.0	286	1560	13.52	32.7
64+	2.47	57.6	1.9	306	1621	12.86	30.1
LSD	NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.23-Analysis of variance on physical, chemical, and sensory characteristics grouped by bushel weight

Variable	DF	Mean Square	MSE	F Value	P
Aroma	3	.934	.514	1.82	.176
Germinate	3	1937.	1239.	1.56	.230
Grade	3	2.367	1.643	1.44	.261
Sediment	3	15.540	102.4	.15	.927
Loaf Vol	3	16517.	32347.	.51	.680
Gluten Ball	3	31284.	25978.	1.20	.334
Protein	3	1735.	4287.	.40	.751
Grain	3	1.166	2.118	.55	.654
Porosity	3	1.595	2.827	.56	.646
Crumbly	3	1.690	3.589	.47	.706
Gummy	3	.580	1.606	.36	.782
Adhesive	3	.154	.778	.20	.896
Chewy	3	.042	1.079	.04	.990
Moist	3	.273	1.125	.24	.866
Rancid	3	.946	.812	1.16	.351
Stale	3	1.478	.910	1.62	.219
Nutty	3	1.431	.248	5.77	.006
Yeasty	3	.178	.209	.85	.483
Salty	3	.075	.069	1.09	.378
Sweet	3	1.048	.443	2.37	.105
Bitter	3	.217	.443	.49	.694
Astringent	3	.418	.500	.84	.492

Table A.24-Means of QDA texture scores grouped by gluten ball volume

Gluten Ball	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
<299	12	5.28	5.46	4.98	5.05	5.36	5.77	5.95
300-399	6	5.67	6.11	5.07	5.11	5.21	5.68	5.75
400-499	3	4.88	5.13	6.01	5.49	5.13	5.71	5.95
500+	3	5.68	6.94	5.93	5.03	5.20	5.88	5.62
LSD		NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.25-Means of QDA flavor scores grouped by gluten ball volume

Gluten Ball	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
<299	3.77	4.88^{b}	4.84	2.69	2.61	3.51	2.61^{b}	2.99^{b}
300-399	3.89	4.99^{b}	5.02	2.49	2.60	3.32	2.56^{b}	2.80^{b}
400-499	5.17	6.54^{a}	4.01	2.58	2.36	2.67	3.60^{a}	3.95^{a}
500+	2.87	4.10^{b}	5.00	2.33	2.37	2.87	2.05^{b}	2.29^{b}
LSD	1.03	1.12	NS	NS	NS	NS	.74	81

Numbers with different superscripts are significantly different.

Table A.26-Means of chemical and physical tests grouped by gluten ball volume

Gluten Ball	Grade	Germinate	Bushel Weight	Sediment	Protein	Loaf Vol
<299	2.41	39.6	63.03	27^{b}	12.54^{b}	1576
300-399	2.33	38.7	62.63	29^{b}	13.14^{ab}	1528
400-499	3.00	16.3	62.37	33^{b}	15.20^{ab}	1588
500+	2.33	62.5	62.20	48^{a}	15.51^{a}	1723
LSD	NS	NS	NS	10	2.42	NS

Numbers with different superscripts are significantly different.

Table A.27-Analysis of variance on physical, chemical, and sensory characteristics grouped by gluten ball volume

Variable	DF	Mean Square	MSE	F Value	P
Aroma	3	2.350	.301	7.81	.001
Bushel Weight	3	.798	6.350	.13	.944
Germinate	3	1065.	1370.	.78	.520
Grade	3	.347	1.946	.18	.910
Sediment	3	352.8	51.830	6.81	.002
Loaf Vol	3	25870.	30944.	.84	.490
Protein	3	10.76	2.933	3.67	.030
Grain	3	.534	2.223	.24	.867
Porosity	3	2.319	2.706	.86	.481
Crumbly	3	1.301	3.654	.36	.785
Gummy	3	.156	1.676	.09	.963
Adhesive	3	.062	.793	.08	.971
Chewy	3	.030	1.081	.03	.993
Moist	3	.116	1.151	.10	.958
Rancid	3	2.729	.515	5.30	.008
Stale	3	3.226	.619	5.21	.009
Nutty	3	.166	.359	2.13	.132
Yeasty	3	.115	.219	.52	.672
Salty	3	.083	.068	1.22	.330
Sweet	3	.723	.497	1.46	.260
Bitter	3	1.281	.265	4.83	.012
Astringent	3	1.486	.322	4.62	.014

Table A.28-Means of QDA texture scores grouped by sedimentation value

Sediment	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
<28	12	5.27	6.55	5.97	5.13	5.32	5.52	5.76
29-39	9	6.07	5.58	6.08	4.75	5.11	5.84	5.89
40-49	2	3.97	4.88	3.36	5.91	5.43	6.83	6.53
50+	1	5.69	5.91	4.71	5.71	5.14	6.04	5.34
LSD		NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.29-Means of QDA flavor scores grouped by sedimentation value

Sediment	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
<28	4.19	5.39	4.72	2.74	2.63[a]	3.34	2.91	3.20
29-39	3.34	4.17	5.20	2.35	2.51[ab]	3.37	2.11	2.47
40-49	3.82	5.51	4.08	2.28	2.21[ab]	2.62	2.94	3.16
50+	2.98	4.46	4.94	2.31	2.16[b]	2.68	2.05	2.70
LSD	NS	1.72	1.19	NS	.46	NS	1.08	NS

Numbers with different superscripts are significantly different.

Table A.30-Means of chemical and physical tests grouped by sedimentation value

Sediment	Protein	Gluten Ball	Loaf Vol	Age	Grade	Bushel Weight	Storage Condition	Germin ation	Aroma
<28	1.40[c]	1.47[c]	2.07	4.73	2.60	2.73	2.14[a]	2.00	2.95
29-39	2.33[ab]	2.00[bc]	3.17	4.00	2.16	3.33	2.00[ab]	2.67	2.39
40-49	3.50[ab]	3.50[ab]	3.00	5.50	3.00	2.00	3.00[a]	1.00	3.17
50+	4.00[a]	4.00[a]	2.00	1.00	1.00	3.00	1.00[b]	4.00	2.00
LSD	1.33	1.64	NS	NS	NS	NS	1.07	NS	NS

Numbers with different superscripts are significantly different.

Table A.31-Analysis of variance on physical, chemical, and sensory characteristics grouped by sedimentation value

Variable	DF	Mean Square	MSE	F Value	P
Aroma	3	.761	.539	1.41	.269
Bushel Weight	3	11.52	4.742	2.43	.095
Germinate	3	2591.	1141.	2.27	.111
Grade	3	1.175	1.822	.65	.595
Loaf Vol	3	22306.	31478.	.71	.558
Gluten Ball	3	95676.	16319.	5.86	.005
Protein	3	12.56	2.663	4.27	.012
Grain	3	2.381	1.915	1.24	.323
Porosity	3	1.896	2.777	.68	.574
Crumbly	3	4.574	3.108	1.47	.256
Gummy	3	.807	1.568	.51	.678
Adhesive	3	.080	.790	.10	.958
Chewy	3	1.045	.912	1.15	.357
Moist	3	.432	1.098	.39	.759
Rancid	3	1.258	.760	1.66	.212
Stale	3	2.329	.768	3.03	.056
Nutty	3	.700	.370	1.89	.167
Yeasty	3	.292	.190	1.54	.239
Salty	3	.158	.055	2.86	.066
Sweet	3	.437	.545	.80	.509
Bitter	3	1.066	.301	3.54	.036
Astring	3	.779	.439	1.77	.188

Table A.32-Means of QDA texture scores grouped by percent protein

Protein	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
<12.9	11	5.32	5.86	6.28	4.83	5.04	5.46	5.61
13.0-13.9	6	5.14	5.65	5.64	4.90	5.32	5.56	5.71
14.0-14.9	5	6.32	6.47	5.83	5.34	5.52	5.99	6.10
15.0+	2	4.11	4.26	2.99	6.61	5.52	7.06	6.70
LSD		NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.33-Means of QDA flavor scores grouped by percent protein

Protein	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
<12.9	3.85	4.94	5.03	2.59	2.62^{a}	3.66^{a}	2.72	2.83
13.0-13.9	4.26	5.42	4.78	2.88	2.66^{a}	3.29^{ab}	2.74	3.21
14.0-14.9	3.54	4.63	4.65	2.25	2.41^{ab}	2.77^{ab}	2.43	2.79
15.0+	3.61	5.28	4.21	2.36	2.13^{b}	2.56^{b}	2.70	3.37
LSD	NS	NS	NS	NS	.33	.95	NS	NS

Numbers with different superscripts are significantly different.

Table A.34-Means of chemical and physical tests grouped by percent protein

Protein	Gluten Ball	Sediment	Loaf Vol	Bushel Weight	Grade	Germinate	Aroma
<12.9	237[b]	26[b]	1534	63.0	2.45	29.15	3.09
13.0-13.9	299[ab]	30[b]	1608	62.8	2.50	59.00	2.61
14.0-14.9	419[ab]	35[b]	1694	62.2	2.60	34.14	2.33
15.0+	506[a]	53[a]	1512	62.5	2.00	49.35	2.84
LSD	209	.70	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.35-Analysis of variance on physical, chemical, and sensory characteristics grouped by percent protein

Variable	DF	Mean Square	MSE	F Value	P
Aroma	3	.741	.542	1.37	.282
Bushel Weight	3	.741	6.359	.12	.949
Germinate	3	1265.	1340.	.94	.438
Grade	3	.177	1.971	.09	.965
Sediment	3	442.9	38.32	11.56	.0001
Loaf Vol	3	33646.	29777.	1.13	.361
Gluten Ball	3	65092.	20907.	3.11	.049
Grain	3	2.673	1.866	1.43	.266
Porosity	3	2.394	2.694	.89	.466
Crumbly	3	5.968	2.876	2.08	.139
Gummy	3	1.888	1.388	1.36	.286
Adhesive	3	.308	.752	.41	.748
Chewy	3	1.561	.826	1.89	.167
Moist	3	.793	1.038	.76	.529
Rancid	3	.531	.881	.60	.622
Stale	3	.627	1.052	.60	.626
Nutty	3	.433	.415	1.05	.396
Yeasty	3	.389	.173	2.25	.118
Salty	3	.186	.051	3.67	.032
Sweet	3	1.198	.418	2.87	.625
Bitter	3	.111	.461	.24	.867
Astringent	3	.331	.514	.64	.596

Table A.36-Means of QDA texture scores grouped by loaf volume

Loaf Volume	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
<1400	3	5.40	4.42	5.56	5.91^{ab}	5.82	6.44	6.11
400-1499	6	4.73	4.80	4.62	6.06^{a}	5.86	6.29	6.49
1500-1599	5	5.47	5.99	5.63	5.01^{ab}	5.00	5.61	5.55
1600-1699	5	5.84	6.44	6.93	4.36^{b}	4.94	5.08	5.30
1700+	5	5.71	6.93	6.00	4.45^{ab}	4.84	6.62	5.81
LSD		NS	NS	NS	1.63	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.37-Means of QDA flavor scores grouped by loaf volume

Loaf Volume	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
<1400	4.31	5.46	4.82	2.58	2.68	3.39	2.88	3.09
1400-1499	3.53	4.63	4.81	2.73	2.39	3.14	2.33	2.59
1500-1599	4.27	5.34	4.76	2.51	2.60	3.27	3.04	3.27
1600-1699	4.24	5.56	4.68	2.57	2.61	3.17	2.84	3.40
1700+	3.20	4.36	4.96	2.41	2.54	3.44	2.34	2.58
LSD	NS	NS	NS	NS	NS	NS	1.03	NS

Numbers with different superscripts are significantly different.

Table A.38-Means of physical and chemical tests grouped by loaf volume

Loaf Volume	Sediment	Gluten Ball Vol	Protein
<1400	27.	191.	12.96
1400-1499	34.	298.	13.07
1500-1599	32.	348.	13.16
1600-1699	26.	265.	13.02
1700+	33.	416.	13.66
LSD	NS	NS	NS

Table A.39-Analysis of variance on physical, chemical, and sensory characteristics grouped loaf volume

Variable	DF	Mean Square	MSE	F Value	P
Sediment	4	58.33	97.980	.60	.670
Gluten Ball	4	29408.	26094	1.13	.373
Protein	4	1.290	4.515	.29	.884
Grain	4	1.019	2.208	.46	.763
Porosity	4	4.282	2.267	1.89	.159
Crumbly	4	3.744	3.217	1.16	.361
Gummy	4	2.816	1.140	2.47	.084
Adhesive	4	1.073	.598	1.79	.176
Chewy	4	1.285	.847	1.52	.242
Moist	4	1.143	.970	1.18	.355
Rancid	4	1.075	.774	1.39	.279
Stale	4	1.256	.929	1.35	.292
Nutty	4	.0464	.504	.09	.984
Yeasty	4	.0704	.236	.30	.875
Salty	4	.0557	.073	.76	.566
Sweet	4	.0703	.673	.11	.977
Bitter	4	.5204	.385	1.35	.291
Astringent	4	.7131	.435	1.64	.210

Table A.40-Means of QDA texture scores grouped by storage conditions

Storage Conditions	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
Main Floor Uniform Warm	3	5.38	5.61	5.22	5.32	5.35	5.82	5.46
Basement Uniform Cool	13	5.40	5.73	6.03	5.13	5.34	5.70	5.96
Outbuilding Fluctuating	6	5.36	6.04	5.26	5.01	5.07	5.83	5.79
LSD		NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.41-Means of QDA flavor scores grouped by storage conditions

Storage Conditions	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
Main Floor Uniform Warm	3.99	5.32	4.89	2.58	2.50	2.98	2.68	3.21
Basement Uniform Cool	3.81	4.86	4.91	2.49	2.57	3.45	2.65	2.91
Outbuilding Fluctuating	3.93	5.26	4.52	2.73	2.50	2.98	2.66	2.99
LSD	NS	NS	NS	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.42-Means of chemical and physical tests grouped by storage conditions

Storage Conditions	N	Sediment	Loaf Vol	Gluten Ball	Protein	Germinate	Bushel Weight	Grade	Aroma
Main Floor Uniform Warm	3	44.	1565.	453.	14.73	77.5	63.57	1.33	2.44
Basement Uniform Cool	14	28.	1583.	266.	12.79	35.9	63.06	2.28	2.83
Outbuilding Fluctuating	6	33.	1632.	392.	14.35	34.8	61.53	3.17	2.78
LSD		11.	NS	190.	NS	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.43-Analysis of variance on physical, chemical, and sensory characteristics grouped by storage conditions

Variable	DF	Mean Square	MSE	F Value	P
Aroma	2	.1782	.6197	.30	.743
Bushel Weight	2	6.095	5.850	1.04	.371
Germinate	2	2290.	1220	1.88	.179
Grade	2	3.560	1.518	2.35	.122
Sediment	2	331.9	69.03	4.81	.020
Loaf Volume	2	6329.	31798.	.20	.821
Gluten Ball	2	62643.	21739.	2.88	.080
Protein	2	7.941	3.667	2.17	.141
Grain	2	.0023	2.190	.00	.999
Porosity	2	.2567	2.902	.09	.916
Crumbly	2	1.605	3.491	.46	.639
Gummy	2	.0939	1.603	.06	.943
Adhesive	2	.1653	.7440	.22	.803
Chewy	2	.0445	1.024	.04	.958
Moist	2	.3170	1.075	.29	.748
Rancid	2	.0541	.9129	.06	.943
Stale	2	.4689	1.046	.45	.646
Nutty	2	.3229	.4272	.76	.483
Yeasty	2	.1164	.2135	.55	.589
Salty	2	.0112	.0762	.15	.864
Sweet	2	.5957	.5221	1.14	.340
Bitter	2	.0012	.4536	.00	.997
Astringent	2	.1143	.5272	.22	.807

Table A.44-Means of QDA texture scores grouped by storage containers

Storage Container	N	Grain	Porosity	Crumbly	Gummy	Adhesive	Chewy	Moist
Moistureproof	20	5.64[a]	6.11[a]	6.06[a]	4.93[b]	5.18	5.60[b]	5.69[b]
Permeable	2	2.84[b]	2.69[b]	2.16[b]	7.04[a]	6.06	7.32[a]	7.46[a]
LSD		1.81	2.03	2.24	1.64	NS	1.30	1.36

Numbers with different superscripts are significantly different.

Table A.45-Means of QDA flavor scores grouped by storage containers

Storage Containers	Rancid	Stale	Nutty	Yeasty	Salty	Sweet	Bitter	Astring
Moistureproof	3.84	4.98	4.91[a]	2.50[b]	2.57	3.31	2.66	2.95
Permeable	4.12	5.56	3.74[b]	3.33[a]	2.27	2.69	2.60	3.24
LSD	NS	NS	.87	.60	NS	NS	NS	NS

Numbers with different superscripts are significantly different.

Table A.46-Means of chemical and physical tests grouped by storage containers

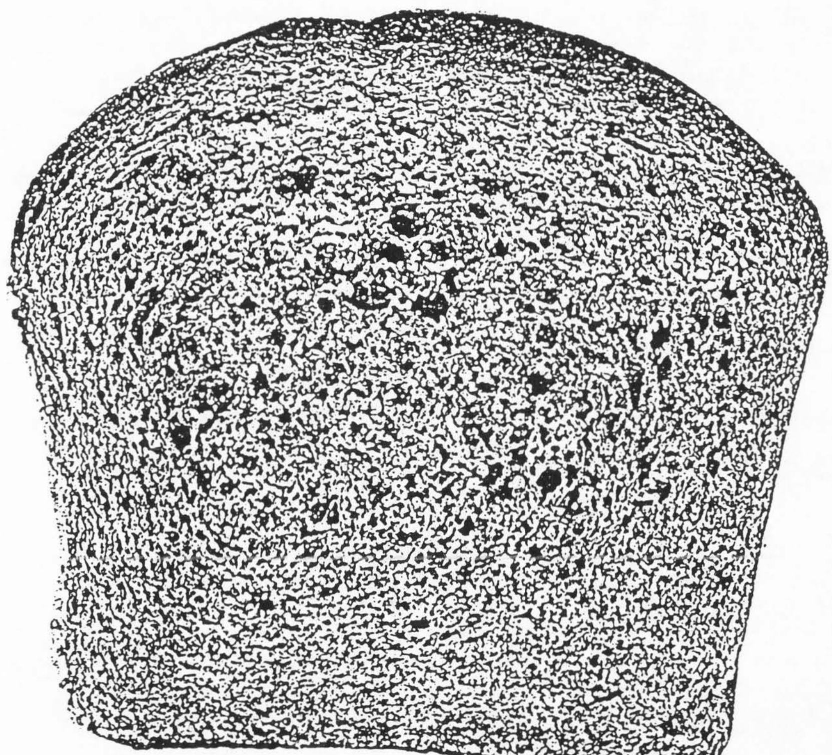
Storage Containers	Sediment	Loaf Vol	Gluten Ball	Protein	Germinate	Bu Wt	Grade	Aroma
Moistureproof	30.86	1602.	319.	13.24	44.1[a]	62.76	2.24[b]	2.68[a]
Permeable	31.67	1458.	269.	14.48	6.00[a]	62.63	4.00[a]	3.56[a]
LSD	11.	NS	NS	NS	44.66	NS	1.54	.91

Numbers with different superscripts are significantly different.

Table A.47-Analysis of variance on physical, chemical, and sensory characteristics grouped by storage containers

Variable	DF	Mean Square	MSE	F Value	P
Aroma	1	2.011	.5028	4.00	.058
Bushel Weight	1	.0434	5.880	.01	.932
Germinate	1	3810.	1218.	3.13	.091
Grade	1	8.149	1.446	5.64	.027
Sediment	1	1.720	95.15	.02	.894
Loaf Volume	1	54288.	29191.	1.86	.186
Gluten Ball	1	6663.	27580.	.24	.628
Protein	1	4.077	3.949	1.03	.321
Grain	1	14.26	1.367	10.42	.004
Porosity	1	21.22	1.723	12.32	.002
Crumbly	1	27.69	2.099	13.19	.002
Gummy	1	8.091	1.128	7.18	.014
Adhesive	1	1.402	.6533	2.15	.158
Chewy	1	5.363	.7092	7.56	.012
Moist	1	5.677	.7694	7.38	.013
Rancid	1	.1441	.8654	.17	.688
Stale	1	.6043	1.011	.60	.448
Nutty	1	2.493	.3134	7.95	.011
Yeasty	1	1.268	.1510	8.39	.009
Salty	1	.1609	.0655	2.46	.133
Sweet	1	.7057	.5203	1.36	.258
Bitter	1	.0073	.04307	.02	.898
Astringent	1	.1620	.5042	.32	.577

APPENDIX B. PHOTOCOPIES OF BREAD SLICES



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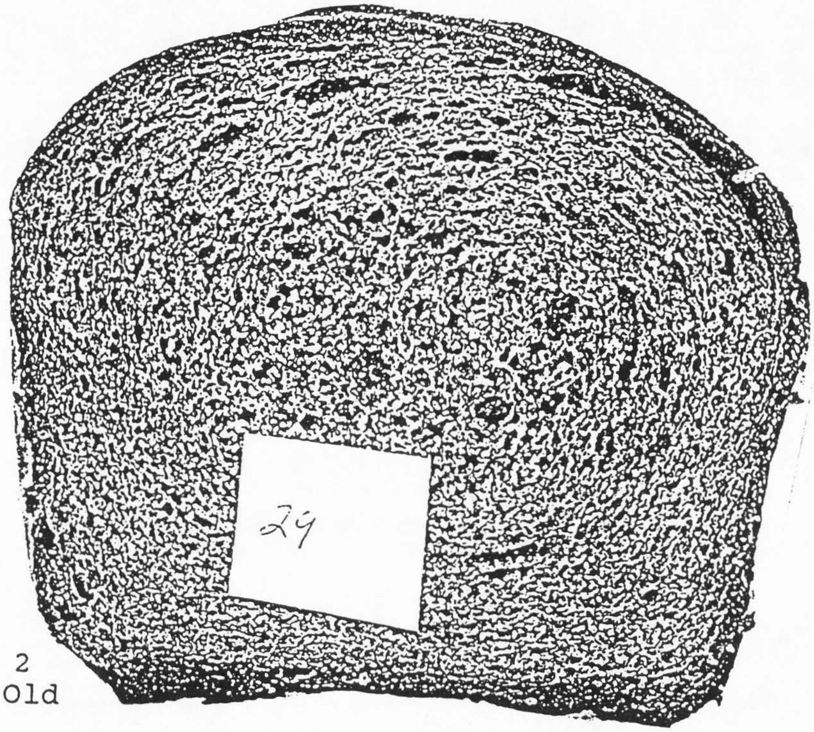
1 Year Old



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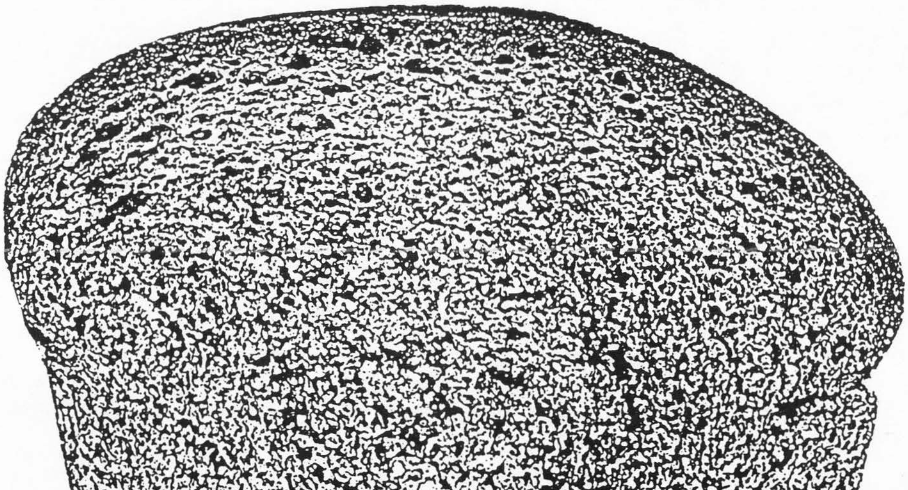
2 Years Old



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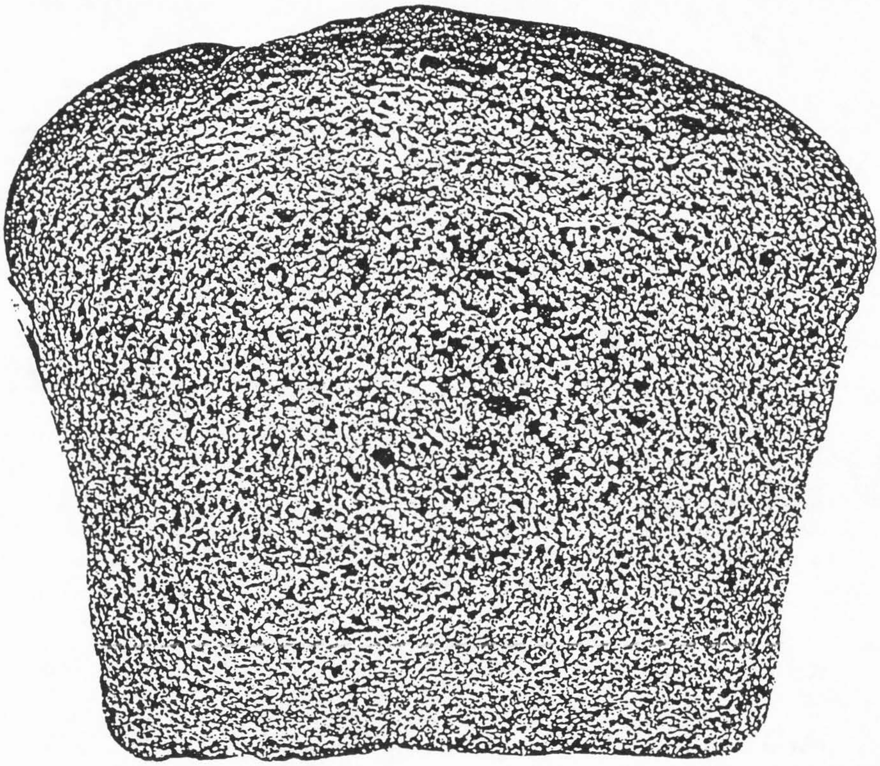
2 Years Old



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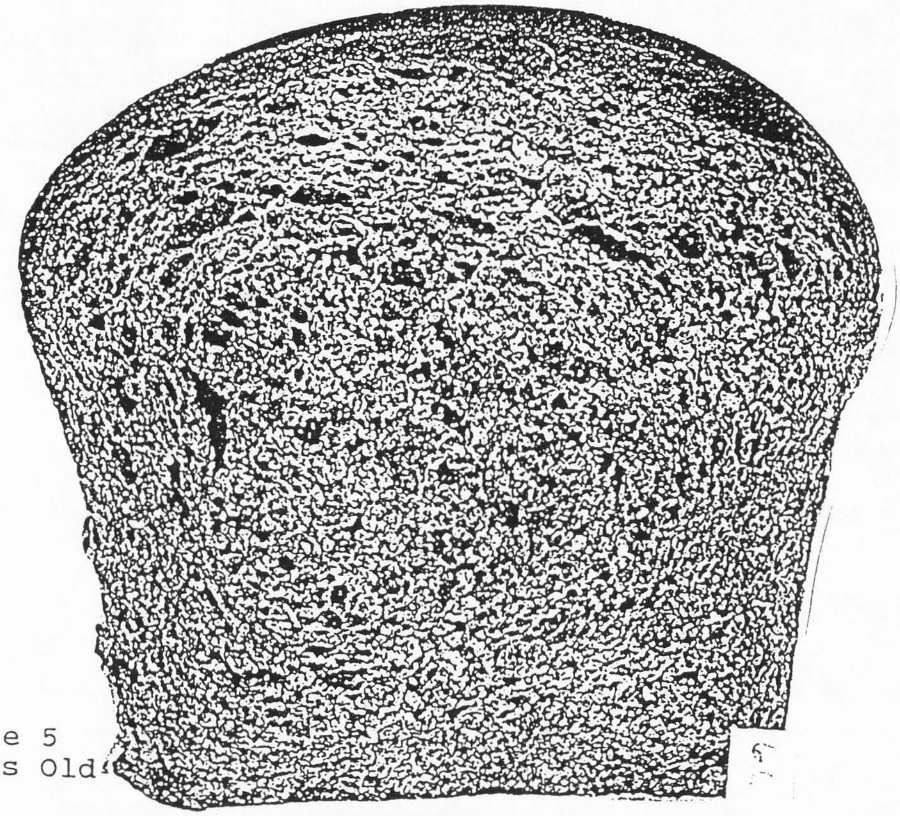

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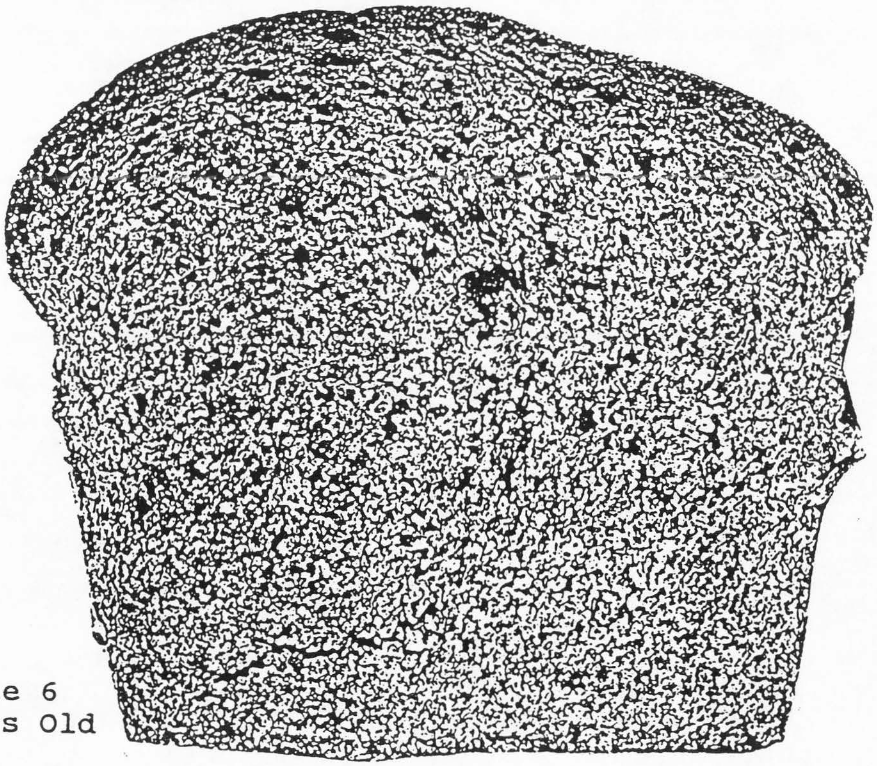

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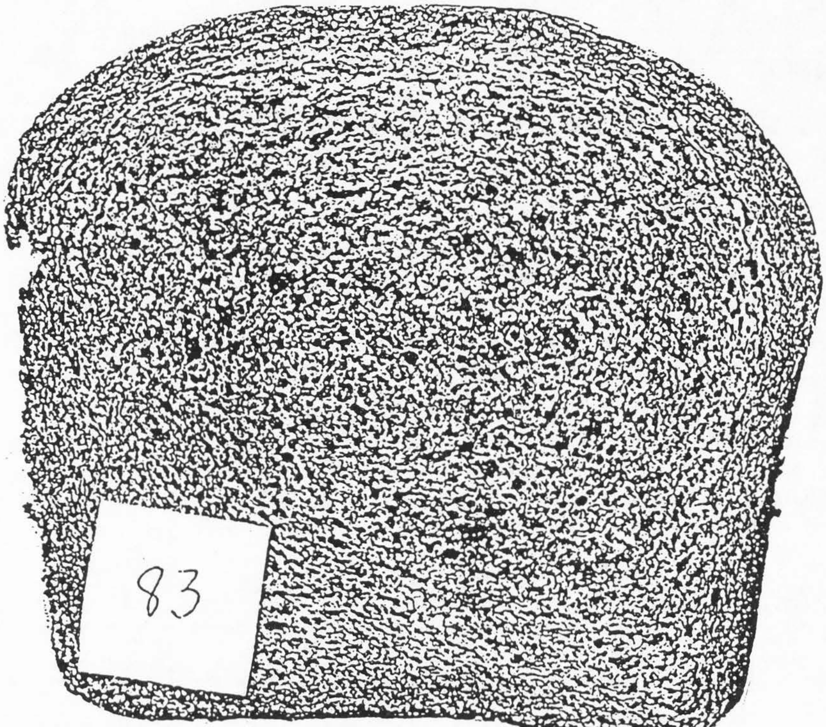

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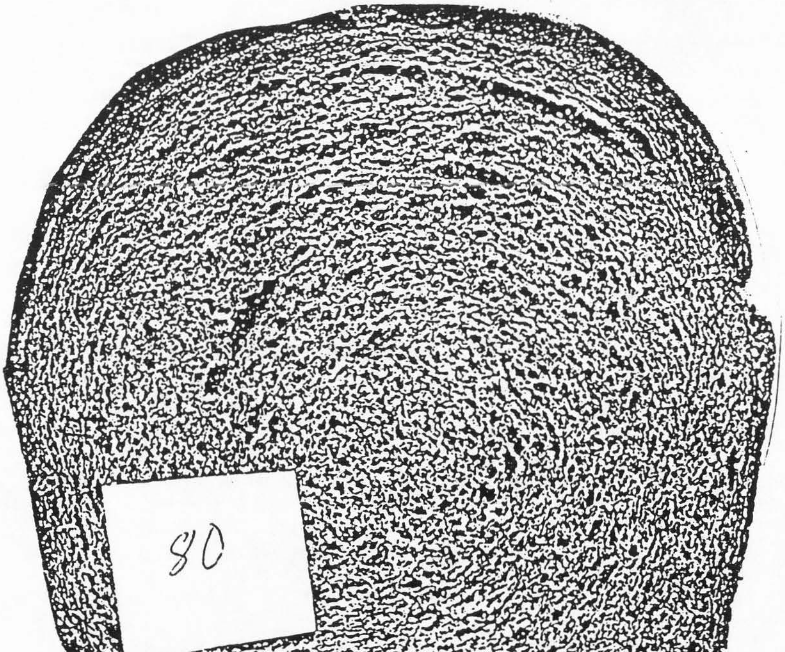

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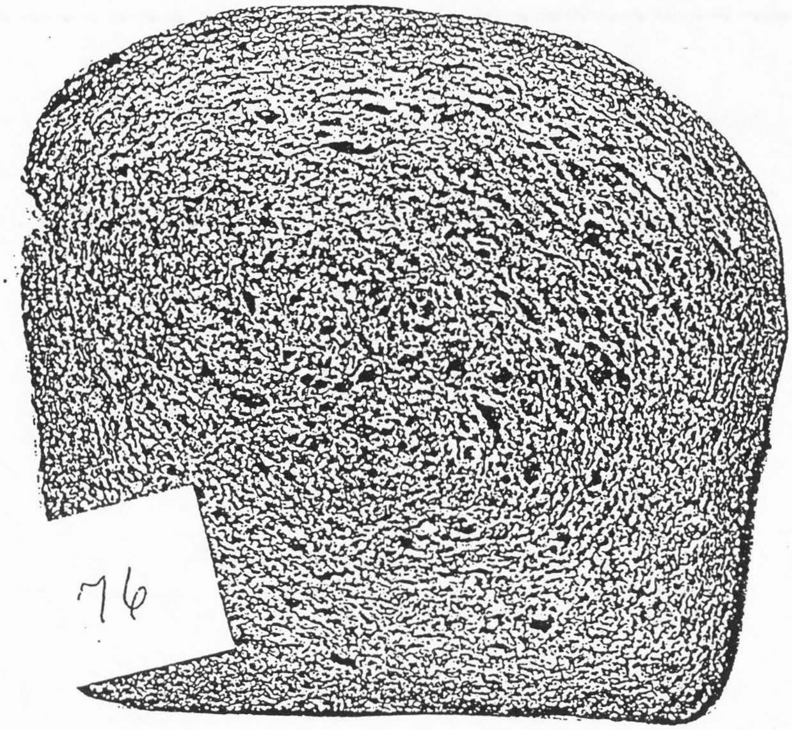

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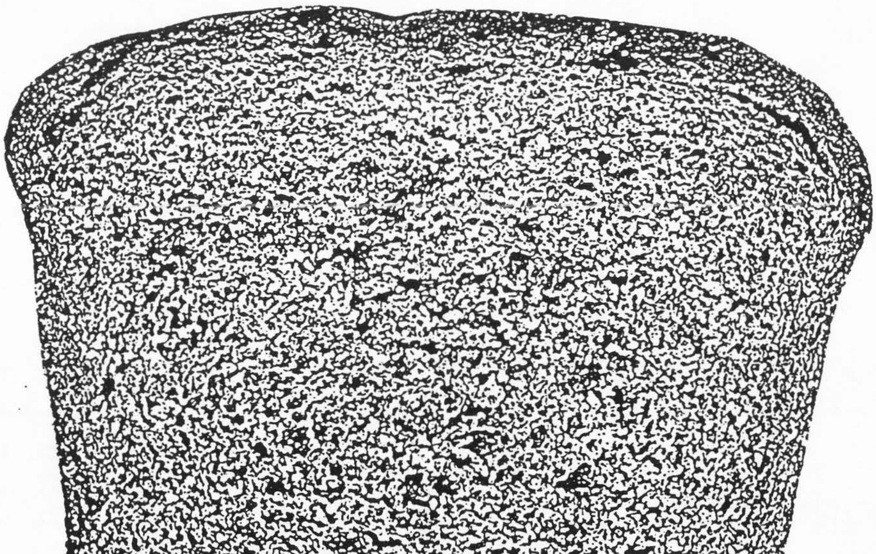

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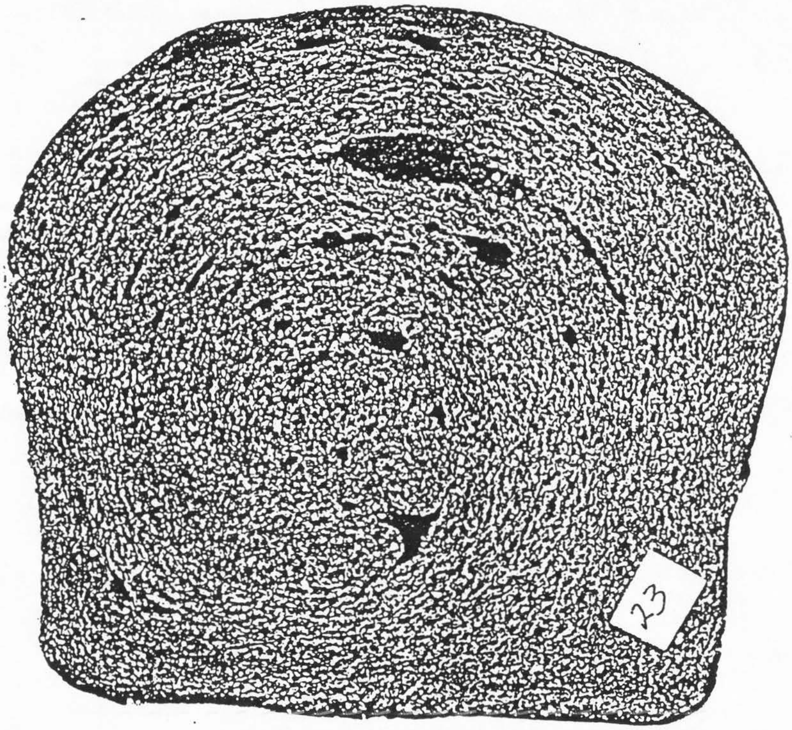

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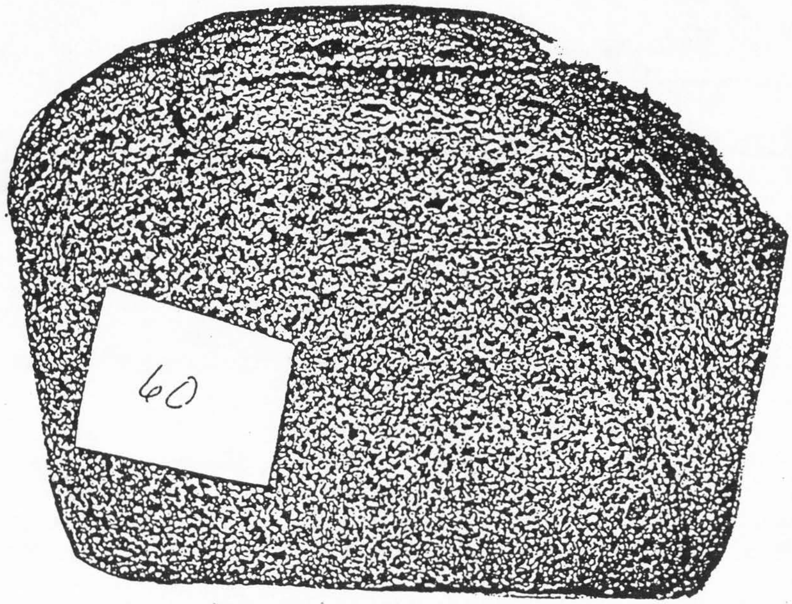

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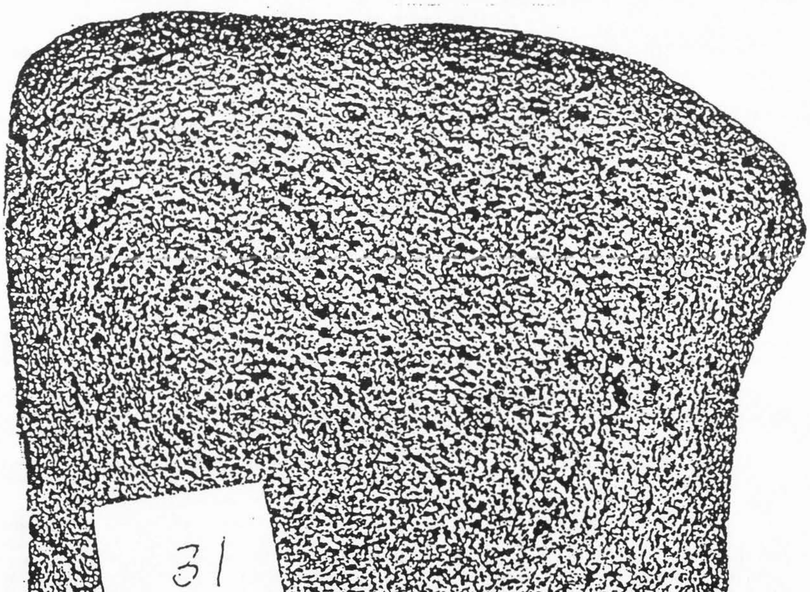
18 Years Old



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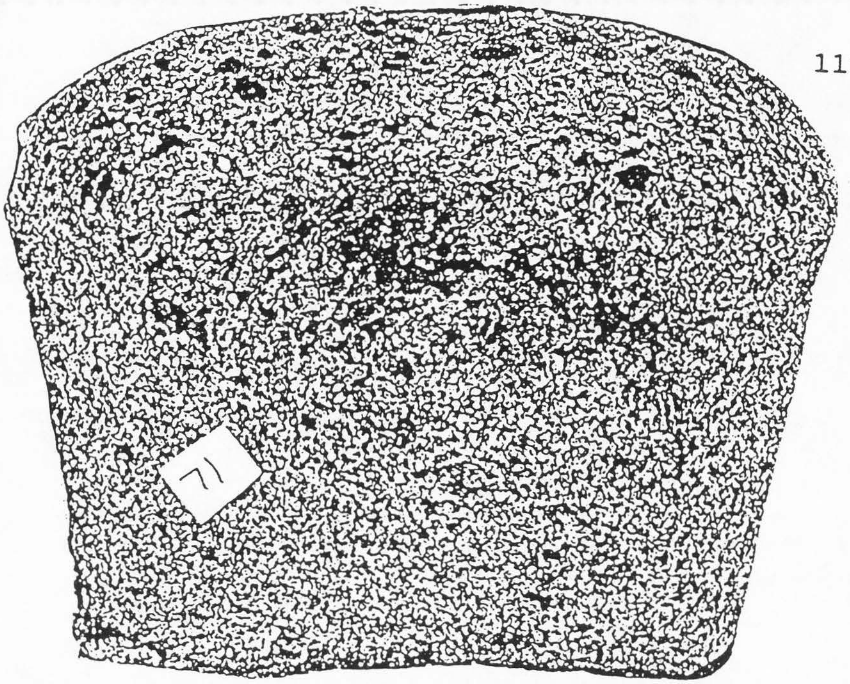
20 Years Old



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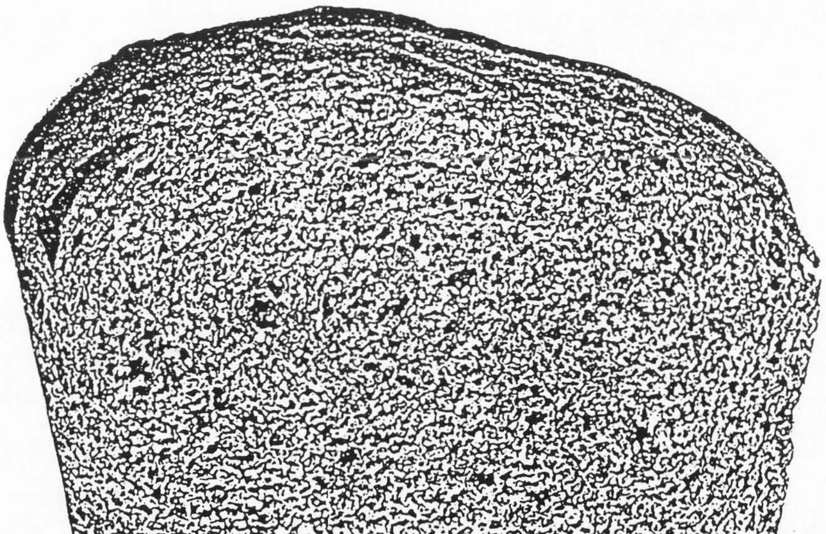

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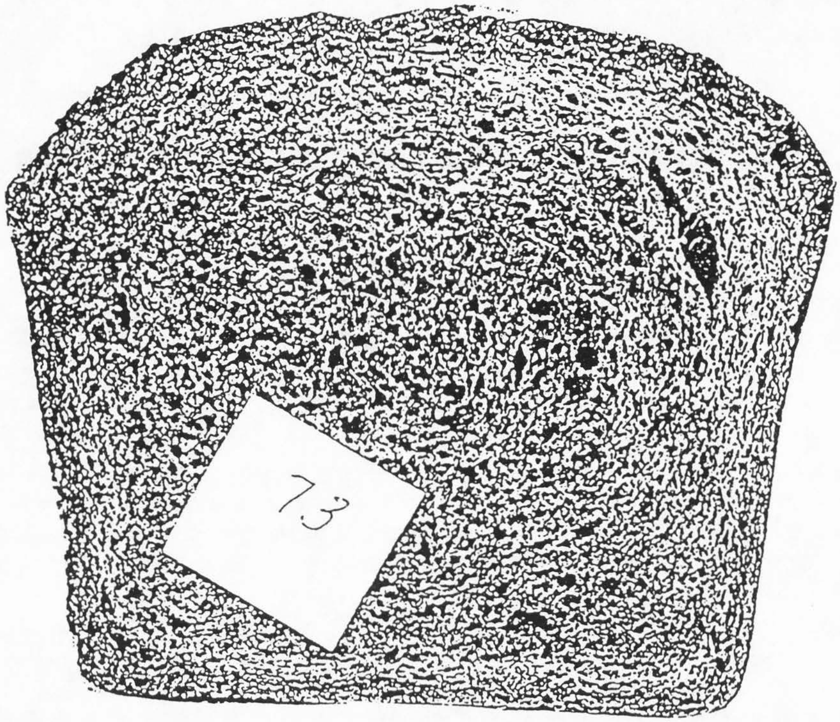
25 Years Old



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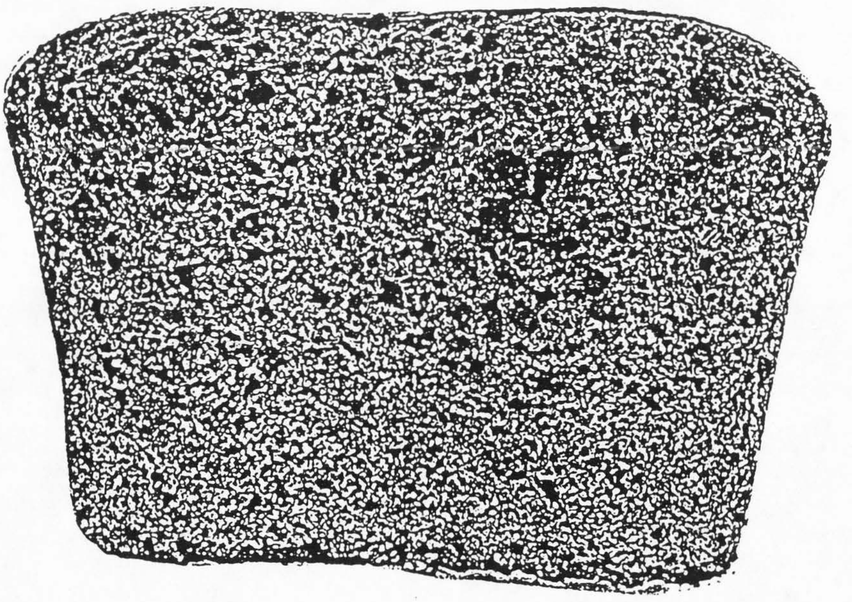
26 Years Old



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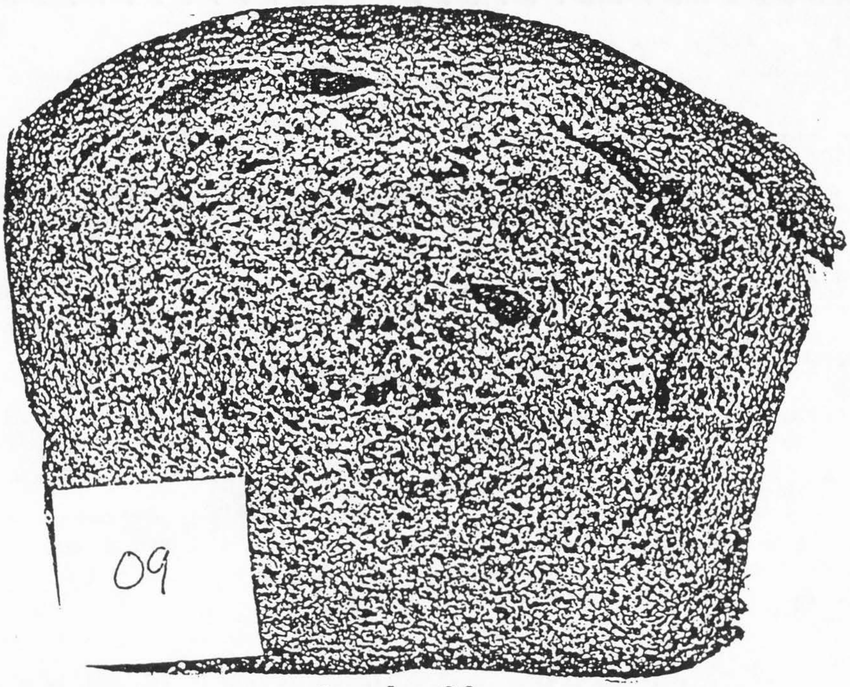

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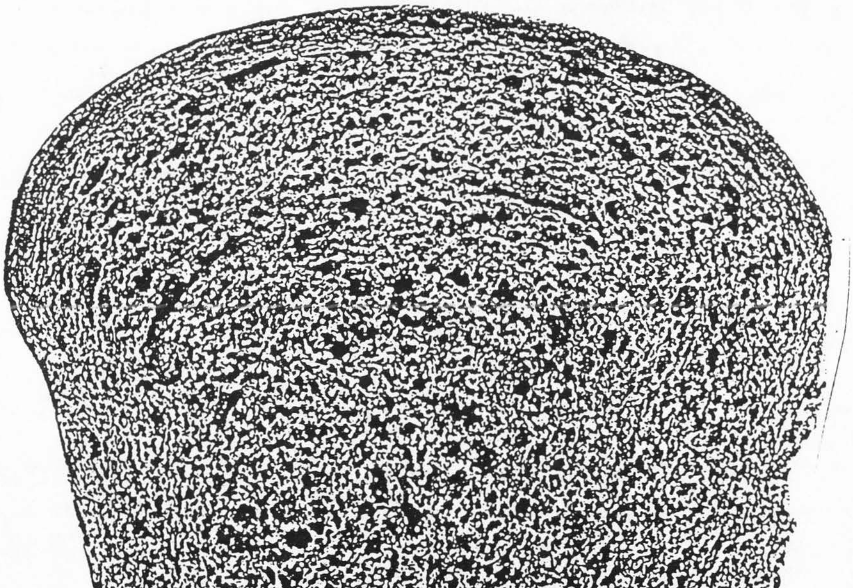

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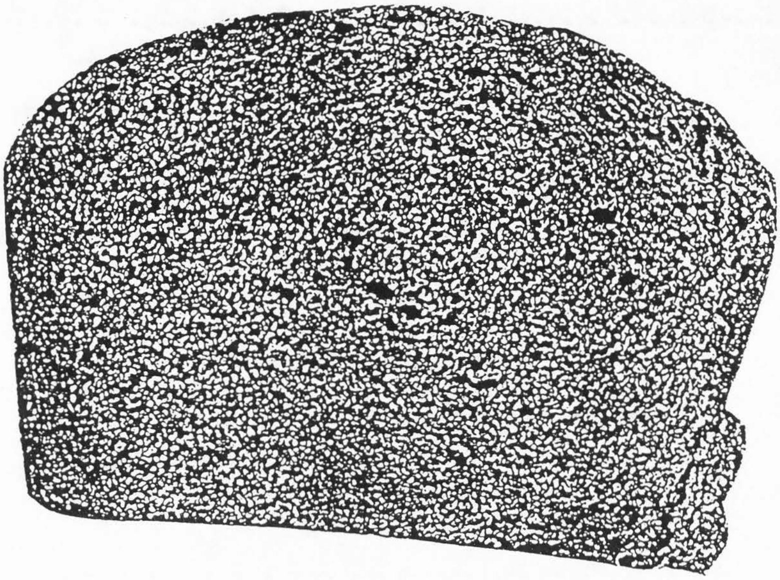
32 Years Old



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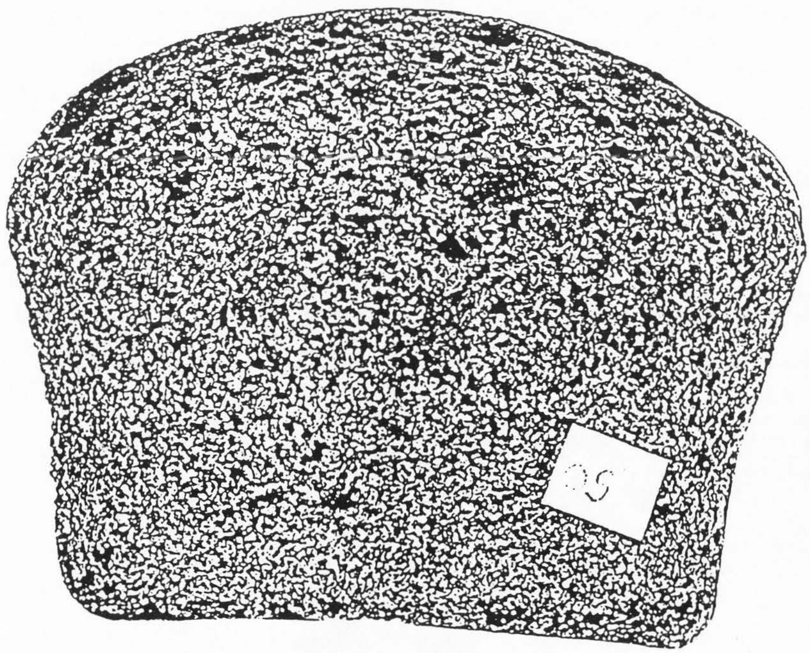
33 Years Old



Sample 24
48 Years Old